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Can agriculture feed the world: a world food analysis

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Can agriculture feed the world:

A world food analysis

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CHAPTER I. INTRODUCTION

During the last two decades the developed nations of the world have given increased attention to the fate of the people in the developing countries. Of primary concern have been the problems of health, population control, food production, and economic development. Through organizations such as the United Nations and its many daughter organizations (Food and Agriculture Organization, International Labor Organization, World Health Organization, United Nations Economic Social and Cultural Organization, United Nations Development Program, to name a few), an enormous amount of talent and finance has been channeled into these countries to find ways to improve the humanitarian conditions under which the present population lives. Other organizations (the Rockefeller Foundation, the Ford Foundation, and the international research institutes) also have contributed considerably to the vast amount of resources engaged in the development problem. Through these organizations, increased research and education have led to the rapid application and use of new technologies in areas such as health, hygiene, and preventive medicine. The ensuing population "explosion" has become, ironically, the major cause of today's food problems.

The world has gone through a number of periods in which its agricultural production capacity was questioned. The most recent food scare, however, is considered to signal a fundamental shift from a situation of long-term surpluses to one of chronic deficits.[1]

Current world food deficits are estimated to affect between 400-500 million people. Exact estimates of how many people who die annually because of malnutrition, and the number of young children who suffer permanent brain damage or physical disability from malnutrition are impossible to obtain. Mankind has awakened to the cruelty of such a situation and has proceeded to instigate some action on a series of frontiers such as health, food production, population control, housing, laws of the sea, and monetary policies.

This study attempts to contribute to the present state of the art by investigating the nature of the apparent food shortage and what role U.S. agriculture could play to help overcome such deficits in the near future.

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[1]Six food crises have been reported since Malthus first noted the pending food disaster in 1789. Malthus argued that man's potential reproductive capability caused an exponential population growth, while the earth's productive capacity would more nearly grow in a linear fashion. The second period of extreme pressures on the food supply occurred in 1898. Sir William Crookes was the instigator. Crookes was mainly concerned with the "bread-eaters" of the world. Little interest was paid to the relatively unknown "third world." Sir William presented evidence that wheat productive capacity was nearly at its peak and the land base nearly exhausted, while population was rapidly increasing. The third period of perceived food scarcity was the period immediately following World War I. Because of the devastation of productive capacity, a temporary food shortage resulted, but only in Europe and for a relatively short period of time. The fourth crisis developed around the early 1950s. Poor weather conditions in many parts of the world combined with less-than-trend production in West Europe resulting in low crop production. From the newly created Food and Agriculture Organization, better estimates were obtained of the extent of food shortages in the poor

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Explanations of the Food Deficit

There are many opinions about the causes that brought on the most recent food scare. One judgment is that the world has nearly reached its limit to feed the present population and will soon be unable to cope with the ever-increasing demand for food. Thus, the surplus food-producing nations hold the ultimate decisions as to ". . . which country will receive. . . food aid and which will not; realizing that regardless of the decisions a goodly number of human beings will die" (The Environmental Fund, 1974). A second opinion in the same vein is that the events in the early 1970s signalled a fundamental shift in the structure of the world food economy. In this view we have entered ". . . a period of more or less chronic scarcity and consequently higher (food) prices" (Brown, 1974). Brown contends that recent developments show that the increased demand for food, coupled with population growth and rising incomes, will exceed the world's productive capacity.

Another viewpoint is more optimistic about the current situation and future outlook. The proponents of this view contend that although the present situation is precarious, it is only a temporary one and may

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nations. These facts led (together with an increasing world population) to the pessimistic views on the food supply. Finally, increased per capita income across the world, a rapidly increasing population, and poor weather in one of the world's most populous regions (South Asia) led to the fifth food crisis in the middle 1960s. The per capita growth rates of food production also slowed down. Thus, a food crisis is by no means a new phenomenon. It has been with us for a long time, and there is no doubt that other food deficit periods will occur.

For a concise report on the previous food crises, see Blakeslee, Heady, and Framingham (1973).

not occur again. It is believed that in the next decade or so the probability is good that world food production will just keep ahead of population growth but that there will be times and places of critical shortage (Paarlberg, 1974). Indeed, the reasons underlying the present food deficit were bad harvests in some of the main food producing countries such as Australia and Russia in the 1972 harvest season. In addition, the anchovy harvest in South America was far below normal. This caused a severe protein shortage for the animal feed industry and resulted in extreme pressures on the soybean market. Concurrently, demand for wheat and feed grains took a quantum jump upward, causing grain prices to skyrocket and a depletion of reserve stocks below emergency levels.[2]

Because U.S. reserve stocks were drawn down drastically in the 1972-73 crop year, American agriculture has not had the opportunity to replenish them, even though U.S. agriculture has been planting "fence-row to fence-row" during recent years. The main reason for the extended strong foreign demand is the number of crop failures in major producing areas (e.g., Russia, India, and Africa). Also, as the affluence of the world increases in general, demand for food will continue to increase, although at a less-than-proportionate rate. Higher per capita income, together with a growing population, has been an important factor in bringing an end to the era of continuous grain surpluses which previously caused low world market prices and depressed farm incomes.

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[2]A sufficient level of grain stocks seems to be a ratio of stocks to exports of about 50 percent (Mackie, 1974).

How critical is the food situation? Have we arrived at the point in time where natural disasters or epidemics must control the world's population in order to feed those that survive? Or is the situation just an aberration, a coincidence of circumstances, which will not likely reoccur? Does the world have the knowledge and capacity to produce enough food to feed mankind at reasonable nutritional levels and reasonable prices. Is it the institutional framework, or lack of it, that causes or contributes to the present problems?

The Role of U.S. Agriculture and the World Food Problem

The United States has long been a major exporter of food commodities and thus has helped to alleviate or prevent malnutrition in many parts of the world.

Many factors cause food to be in ample or in short supply in a particular region or in the world. The supply of food in any country in any year is a function of local weather conditions, domestic productive capacity, foreign exchange reserves, trade policies, and national development priorities. When the domestic food supply falls short of effective demand, most nations will import the shortfall to accommodate demand and to prevent starvation and malnutrition.

Agricultural policy in the United States in the 1950s and the 1960s encouraged production at levels far above what the domestic and export markets could absorb at target prices dictated by these policies. To boost prices above market clearing levels, the government purchased quantities to improve farm prices and farm income. This policy led to ever-increasing reserves. Dumping the grain on either domestic or foreign markets would disrupt the local production and distribution system. Hence, the government engaged in massive food surplus disposal to nations suffering from severe hunger and malnutrition. Although such action was by no means a new policy for the United States,[3] it became a semi-permanent institution in 1954 when the Agricultural Trade Development and Assistance Act, better known as PL 480, was passed. During the latter part of the 1960s this program also became known as Food for Peace. Although later in starting than the United States, other nations (Canada, France, and Australia) joined in the food-aid programs. Food disposal programs continued into the 1970s, but because food aid is usually allocated in fixed dollar amounts, quantities shipped as aid were drastically cut back as shortages developed and prices increased (Tables 1.1 and 1.2).

For more than a decade food aid made up a major portion of food exports. It may not be unfair to say that the disposal of grains, accumulated by the government, evolved into a major tool in the world struggle for freedom from hunger. Food aid also was an effective instrument to stimulate economic development and support of U.S. foreign policy goals. Government-assisted exports have greatly helped in the movement of grain, as is evident from Table 1.1. From 1955 to 1963,

[3] The United States provided large amounts of food to its allies during and after World War II and to the defeated countries after the war.

Table 1.1. U.S. agricultural exports: Quantity of wheat and feed grain exported under government programs and commercial trade, 1955-73[a]

Year Ending June 30	Wheat			Feed Grain		
	Aid	Total Government[b]	Commercial	Aid	Total Government[b]	Commercial
	(thousand metric tons)					
1955	1,881.8	4,206.4	1,977.1	436.4	1,155.3	2,720.4
1956	1,623.6	6,353.1	1,679.2	588.8	4,737.9	2,651.9
1957	1,666.7	9,792.3	3,141.6	698.6	3,910.1	1,994.2
1958	843.1	6,250.5	2,542.1	319.4	1,989.7	5,974.6
1959	567.8	7,451.1	2,388.3	14.8	2,189.7	8,383.1
1960	303.5	8,888.0	2,497.7	284.2	3,047.1	8,052.1
1961	890.1	11,001.8	4,270.8	445.8	2,980.0	8,027.2
1962	67.8	11,446.5	5,102.3	63.5	3,323.0	10,840.8
1963	30.4	11,240.1	3,317.1	12.8	1,567.0	13,256.4
1964	13.7	11,226.6	9,311.7	--	1,206.4	14,386.4
1965	2.6	13,417.3	3,882.7	11.3	1,044.9	16,520.9
1966	4.6	12,783.9	8,594.6	7.6	2,017.2	23,419.0
1967	59.7	7,133.8	10,985.9	4.4	3,507.6	17,335.7
1968	20.3	9,389.6	9,669.8	1.5	1,707.4	17,800.7
1969	41.2	5,257.5	7,568.8	1.4	787.3	15,049.2
1970	--	5,776.2	8,669.9	--	1,197.5	17,799.3
1971	26.3	5,093.0	13,243.0	--	1,165.2	17,792.9
1972	20.5	5,198.1	10,478.8	--	1,386.0	19,416.6
1973	-3.2	2,943.7	27,959.4	--	1,452.0	33,922.0

[a]SOURCE: U.S. Department of Agriculture, 1974e.

[b]The "Total Government" column consists of local currency sales, dollar credits, government-government transactions, voluntary relief, barter, and aid. Only aid is broken out of total government exports in this table.

government-assisted sales accounted for more than 25 percent of total grain exports. Since 1966 the government share has declined considerably with a low of 8 percent in 1973 (Table 1.2). The value of government sales has been rather stable. On the other hand, commercial sales have increased rapidly, reflecting the high grain demand in recent years.

Wheat and feed grains have been emphasized in government programs (U.S. Department of Agriculture, 1974e). The government exported more wheat than the commercial sector during the period 1955-66. Government-assisted exports decreased substantially for food and feed grains over the period 1955-73 and were virtually eliminated in 1973 (Table 1.1).

United States commercial grain exports have increased steadily over time. Recently, however, they have been accentuated by large increases in export demand. There are a number of reasons that may explain this strong demand for U.S. exports:

1. The increase in population worldwide. It is estimated that world population increases by about 70 million annually and will nearly double (to 6.4 billion) by the year 2000. In particular, strong population growth is predicted to take place in those countries where domestic food production has fallen behind, thus necessitating imports.[4]
2. Income levels have increased steadily over the world. The elasticities of demand for food with respect to income are close

[4]It seems that public policy has shifted with respect to imports of food and feed. Although domestic deficits used to be overcome by slaughter of cattle and rationing, recent shortfalls have been made up by increases in imports.

Table 1.2. U.S. agricultural exports: Value, specified government-financed programs, commercial, and total fiscal years 1955-73[a]

Year Ending June 30	Total Government	Commercial	Total	Percent of Government Total
		(thousand dollars)		
1955	835,071	2,309,147	3,144,218	26.6
1956	1,339,373	2,156,288	3,495,661	38.3
1957	1,919,382	2,808,860	4,728,242	40.6
1958	1,208,437	2,794,535	4,002,972	30.2
1959	1,227,124	2,492,231	3,719,355	33.0
1960	1,283,023	3,235,951	4,518,974	28.4
1961	1,502,399	3,443,918	4,946,317	30.4
1962	1,569,169	3,572,874	5,142,036	30.5
1963	1,469,688	3,607,931	5,077,619	28.9
1964	1,441,448	4,626,132	6,067,580	23.9
1965	1,596,176	4,500,658	6,096,834	26.2
1966	1,388,533	5,287,891	6,676,424	20.8
1967	1,308,149	5,463,182	6,771,331	19.3
1968	1,296,911	5,014,560	6,311,471	20.5
1969	1,050,071	4,691,287	5,741,358	18.3
1970	1,068,239	5,653,128	6,721,367	15.9
1971	1,078,595	6,678,979	7,757,574	13.9
1972	1,123,529	6,923,023	8,046,552	14.0
1973	1,030,190	11,863,822	12,894,012	8.0

[a] SOURCE: U.S. Department of Agriculture, 1974e.

[b] NOTE: This table includes all exported agricultural commodities.

to zero and even negative in the developed countries, but they are relatively high in the developing countries. Additional increases in income thus lead to increased demand for food and, consequently, exports (Food and Agriculture Organization, 1975).

3. Adverse weather conditions in many regions of the world have led to decreased food production, necessitating additional imports.

Agricultural imports can fluctuate extensively, primarily because production depends to a large degree upon the domestic weather situation. Crop shortfalls usually lead to increased import demands from surplus-producing nations. Because the United States is the world's largest marginal food exporter and exports such a large proportion of its production, variations in production elsewhere can have a great impact on U.S. export demand (Heady, Faber and Sonka, 1975). It seems that adverse weather conditions elsewhere in the world are the main reason for the volatile demand for U.S. exports. Indeed, the years of large increases in exports are those which coincide with years of crop shortfalls elsewhere (Mackie, 1974).

Government food aid and commercial exports are the most important factors in the distribution of food to those who need it most and those who can afford it best, respectively. On the one hand, in time of relative abundance, food aid and other government-subsidized exports are of importance in the overall movement of grain stocks to those who are in need of it. On the other hand, when supplies are short the market mechanism revives, grain prices are bid up, and grain will move to where the dollar vote directs it.

Objectives of This Study

The world food scarcity that has developed in recent years has led "surplus" producing nations to make a large effort to bridge the gap between desired demand and supply of food. This effort has certainly been successful in the United States. Record grain exports were made, both in terms of quantity and value in 1973, 1974, and 1975. Notwithstanding the expansion of exports, many areas and countries continue to experience food deficits. The "food deficit" nations, themselves, attempt to increase domestic production. However, in many nations population increases faster than agricultural production leading to an increase in food deficits and imports. Therefore, as the world makes an effort to feed the population, the role of agriculture in the "surplus" countries is likely to become more important.

The objective of this study, then, is to analyze the role American agriculture can play under different future food production and consumption levels for the world, and to indicate some of the impacts of these levels on the U.S. farming industry.

World food consumption is a major variable that determines the productive effort of agriculture as well as the magnitude of exports from the United States. In fact, the level of agricultural exports is an important parameter differentiating between six alternative futures based on projection to the year 1980. These alternatives are explained below, but will be more fully discussed in Chapter 4.

The first alternative assumes that U.S. agriculture will make an all-out effort to produce food and feed grains. In this case the level of exports would be determined by the limit of the land base, allocated to the export crops. Because U.S. agricultural export capacity is determined by domestic production and consumption, the second alternative supposes that the world population must be fed at levels commensurate with a set of recommended daily allowances for each individual. Under this view, U.S. exports will increase to the level where no food deficit exists. A third alternative of future exports is dictated by the requirement that all nations be fed at least at recommended levels. Individual countries, however, may consume more as economic variables permit. A fourth alternative reflects a situation in which an overall yield decrease comes about because of a widespread drought, or some other natural disaster. A fifth scenario assumes that the developed nations reduce meat consumption per se. Finally, a sixth situation requires U.S. exports to accommodate crop failures in other major food-producing countries. Under this alternative a considerable effort is made to reduce demand for grain through a reduction in meat consumption. Substitution of sufficient plant protein for the reduced animal protein intake is assumed.

Six alternatives are implemented and the results analyzed in this study. The alternatives are differentiated by two parameters, exports, and consumption. Under each alternative some of the key variables are analyzed; the quantity and location of production, supply prices for the commodities, and the extent of continued malnutrition.

The outlook for world agricultural production and demand will be discussed in Chapter II. Chapter III presents details about U.S. agriculture and its policies. Chapter IV relates the statistical and linear programming techniques used for the model. The model will also be presented in detail. Chapter V presents a discussion of the results. Finally, Chapter VI summarizes the procedures, results, implications, and limitations of the study.

CHAPTER II. STRUCTURE OF WORLD AGRICULTURE

The recent food crisis has generated a dim view of the medium- and long-term possibilities for feeding the additional 70 to 80 million humans born every year. Livability on earth is bound to deteriorate under such an explosive increase of people. It has been predicted for ages that if mankind does nothing to slow down the rapid increase in population or to increase agricultural productivity, the inhabitants of this planet will ultimately have to live in misery--at the level of subsistence whence we came hundreds of years ago.

This chapter will discuss the world's agricultural potential. Development of such potential is of primary importance for the starving millions who require relief.

Related Studies

A great number of papers, quantitative models, and other studies have been generated in the face of the world food situation. Only those studies which are related to the present one will be briefly discussed. The first group of studies that has definitely created an awareness of the world's food predicament are three studies: a) Dynamics of Growth in a Finite World (Meadows, Behrens, III, Meadows, Naill, Randers, and Zahn, 1974); b) Man at the Turning Point (Mesarovic and Pestel, 1974); and c) Model of International Relations in Agriculture (de Hoogh, Linneman, Keyzer, and van Heemst, 1976).

These studies point out to the reader the finiteness of the world's resources (of which food is only one) and how close mankind has come to the absolute limit of the capacity of the world to maintain itself. However, these studies use models which are so aggregated that the information provided by these models means little. Some of the functional forms chosen for the models have the exponential growth characteristics Thus, the models often "blow up" because of such functions. Also, the data base used, or the bounds applied to the models, are inaccurate or outdated in a number of cases. However, the most serious shortcoming of these studies may be the fact that technological change is not accounted for; i.e., these models assume a "base technology" and leave it at that level throughout the period which the model covers. How technology is incorporated into these models is epitomized by statements such as "the agricultural inputs per hectare. . . in 1900 must have been relatively small, given that most of the modern inputs had not yet been invented or were only rarely available" (Meadows, Behrens, III, Meadows, Naill, Randers, and Zahn, 1974). Another shortcoming of these models is that they assume fixed input-output ratios and allow no substitution of inputs. In general, it can be said that the above studies have identified a number of important relationships (pollution, fertility of land, erosion, etc.) with which mankind must deal to prevent deterioration of the quality of life.[5]

On the other hand, a number of studies have been published which look at the agricultural sector by itself (rather than part of a

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[5] A critique on one of the models is provided by Haq (1972).

multi-sector model). These studies have modeled agriculture in much greater detail and in general are not nearly so pessimistic about the future. Production and demand are determined on a country or regional basis to bring into account local or regional conditions such as population growth rates, land availability, per capita income, etc. These models are much less aggregated and in turn, provide much more detail about the agricultural sector.

A number of research groups have been involved in such an effort. Both the Food and Agriculture Organization (FAO) and U.S. Department of Agriculture's Economic Research Service (ERS) have regularly analyzed world agricultural development, production, and trade (Food and Agriculture Organization, 1971; U.S. Department of Agriculture, 1967, 1970, and 1974d). Also, a rather intensive study has been completed at Iowa State University that includes an agricultural world trade model for outputs as well as inputs (Blakeslee, Heady and Framingham, 1973). Finally, a recent study completed at Iowa State University's Center for Agricultural and Rural Development (CARD) analyzes the impact U.S. agriculture can have on the world food situation, if certain production and consumption alternatives are adopted. These studies project food production and demand into the future under different income and population growth rates.

Food and Agriculture Organization study (1971)

This study projects an improvement in world agricultural production during the remainder of the present decade. However, it predicts that on a per capita basis the developing countries may see only a limited improvement because of the high rate of population growth. The study emphasizes nutrition and concludes that significant calorie shortages will persist into the 1980s.

The FAO projections are based on an analysis completed before the recent food and energy crisis. The commodities included in the analysis are most of the agricultural products, including fishery and forestry products. Demand and production projections are made for 1980 for a number of commodities.

One hundred and thirty-two countries are included in the study, accounting for about 99.6 percent of the population. The population assumption used is the United Nations "medium" projection as estimated in 1968 and later updated for some 60 countries in 1971. Gross National Product estimates are based on trend growth rates for the developed countries, while for the developing countries two growth rates are used: a) the trend growth rate based on past trends, and b) a "high" alternative based on targeted growth rates established for the Second Development Decade. A constant base price is used for productions, and it is assumed that agricultural policies will remain the same over the projection period. Technology is projected to increase at the same rate as in the past.[6]

[6] The FAO assessment study, taking into account the recent food and energy crises, projects a net deficit of 85 million metric tons of grain for the developing countries. The deficit is a result of both the increase in population as well as the growth in Gross National Product (GNP) (i.e., as per capita income increases, the consumer will increase his demand for food but by a proportionately smaller amount than his increase in income).

U.S. Department of Agriculture study (1974d)

The U.S. Department of Agriculture study also makes its projections to 1985 and concentrates on the major commodities. The study encompasses cereals, oilseeds, and livestock products as well as a number of additional crops such as natural fiber. It also takes into account the existing interrelationship within the cereals-oilseeds-livestock sectors.

United States Department of Agriculture's projections have been concentrated on major countries and major regions of the world rather than on a summation of individual countries. These regions then sum to a world total.

Population growth rates are used for both the world (excepting the United States) and the United States, assuming population growth rates are the United Nation's "medium" variant and U.S. Department of Commerce's Series E, respectively. Income projections are made on the basis of per capita private consumption expenditure (PCE) or, if not available, gross domestic product and net material product as a demand indicator. Present policies are assumed to continue throughout the projection period. Increases in technology are assumed to continue based on historical trend.

The results of the U.S. Department of Agriculture projections are reported for wheat, coarse grain, and rice. In general, the projections confirm those of other studies; namely, moderate per capita increases in food consumption in the next decade. Under the first alternative, per capita cereal consumption is projected to increase from 185 kg in

1970 to 195 kg in 1985.[7] Production is projected to grow slightly faster than population, improving per capita consumption levels. The total increase in grain imports for the developing economies would total about 55 million metric tons compared with 20 million tons in 1970-71 (Table 2.1).

The second alternative, which represents high investment in food production and by embarking upon a policy of increasing the bundles of inputs used to produce food, would generate grain imports in the developing economies up to 23 million tons.

The effects on production and consumption caused by higher fertilizer usage and, consequently, other inputs (such as seed, pesticides, etc.) would reduce grain imports to 16 million tons under alternative two. This situation could be brought about by an additional 15 million tons of fertilizer with accompanying technology. Although the excess supply capacity of the fertilizer industry is far greater than the required 15 million tons, the cost of production and transportation may be beyond the means of the countries which must produce the additional grain (Table 2.1). (The U.S. Department of Agriculture study has analyzed four alternatives. For brevity only two are reported in this study--alternatives I and IV).

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[7]The U.S. Department of Agriculture analysis has taken into account the increase in grain and energy prices since 1972. Even so, it is predicted that, under the high-demand alternative, real prices in 1985 will be below the 1974 level.

Table 2.1. Comparison of cereal projections to 1985[a,b]

Item	FAO base (1969-71)	FAO 1985	USDA base (1969-71)	USDA-I 1985	USDA-II 1985	ISU 1985
			(million metric tons)			
World						
Demand	1,207	1,725	1,062.6	1,548.5	1,643.9	1,145.5
Production	1,239	NS[c]	1,081.8	1,550.4	1,645.7	1,187.3(L)
Balance[d]	+32	NS	19.2	1.9	1.9	1,191.7(H)
Developing countries						
Demand	590	929	466.6	691.2	743.5	
Production	585	853	443.1	632.4	721.0	
Balance	-5	-76	-23.5	-58.8	-22.5	
Developing economies						
Demand	386	629	299.7	479.4	529.1	524.7
Production	370	544	279.2	424.7	513.3	411.0(H)
Balance	-16	-85	-20.5	-54.7	-15.8	406.6(L)
						-113.7(H)
Asian centrally planned countries[e]						-118.1(L)
Demand	204	300	166.9	211.8	214.4	
Production	215	309	163.9	207.7	207.7	
Balance	+11	+9	-3.0	-4.1	-6.7	

Developed countries[f]						
Demand	617	796	596.0	587.3	900.4	403.4
Production	654	NS	638.7	918.0	924.7	574.0
Balance	+37	NS	42.7	60.7	24.3	170.6

[a] The date for FAO and USDA are not comparable because FAO carries rice as paddy and the USDA carries rice as milled.

[b] NOTE: Detail may not sum to total because of rounding.

[c] NS = not shown.

[d] Imbalances for USDA between demand and production in base are due to stock buildup, timing of shipments, and missing data on a number of small importers. Projected equilibrium does not allow for building or reducing stocks.

[e] FAO Asian centrally-planned countries include the People's Republic of China and other Asian centrally-planned countries (North Korea, North Vietnam, etc.), while USDA includes only the People's Republic of China.

[f] Includes the USSR and Eastern Europe.

Iowa State study (1973)

The Blakeslee, Heady and Framingham study, which may be the most extensive to date, has included in its analysis a detailed soil survey of the whole world with the exception of the People's Republic of China. The survey takes into account soil fertility, water supplies, location, transportation to main population centers, and numerous other factors. In addition, a detailed international trade model is utilized, resulting in an optimal transportation pattern for both inputs and outputs.

Projections are based on 1965 data, thereby excluding some of the momentum obtained by the Green Revolution in the late 1960s. Thus, projections may somewhat underestimate the production capacity of the developing countries and, therefore, overestimate import demand.

The study covers 73 crops and agricultural commodities. Projections are made for 9 food commodities or groups: cereals, raw sugar, root crops, pulses, fruits and vegetables, oil crops, meat, milk, and eggs. The 96 countries covered are grouped into major regions and results are presented for these regions.[8] The population estimates (high-medium-low) have been derived from United Nation's (UN) estimates in 1963. Income projections are based on past trends in income for all but 12 countries. The 12 countries are assumed to grow at the same rate as nearby and similar countries. Per capita consumption expenditure data are used, if available; otherwise, gross domestic product, net material product, or net domestic product data are used for income. Prices are projected

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[8]The People's Republic of China was excluded from the analysis for lack of data.

from a 1965 base price, while the policies in effect at the time are assumed to continue.

The ISU study projects an increasing gap between production and consumption in the developing countries--a deficit of 114-118 million tons in 1985 (Table 2.1). However, the basis of the projection is the early 1960s, thus the latest increases in technology through the Green Revolution are not considered. Also, the low grain prices that prevailed in the early 1960s did not provide much incentive for farmers in developing countries to increase production.

Center for Agricultural and Rural Development study (1975)

A different angle of the world food situation is presented in a study by Heady, Faber and Sonka (1975). This study is concerned with the role of agriculture and the agricultural production potential of the United States and makes a set of assumptions about consumption and production patterns. The U.S. population projection is based on the Series E of the U.S. Department of Commerce (1971). Income projection also is based on this series. Yields and technology are projected to 1980, based on trend estimates.

The results show that an additional 50 million tons of grains could be produced over the base alternative of 142.4 million tons if the American consumer would reduce his meat consumption by 25 percent, substitute 25 percent soy protein for animal protein in his remaining meat consumption, and substitute 25 percent silage for feed grain fed to beef. Because the model is solved in a linear programming framework, crops are distributed among regions according to their comparative advantage. The results of this study tend to indicate that even the largest deficits in the developing countries as projected by the studies discussed previously could be covered by possible U.S. exports alone.

All the studies discussed in this section have projected as accurately as possible production and demand in major regions (or countries) of the world, making different assumptions about growth of population, income, production, and trade. The studies are cautiously optimistic about the world's ability to produce enought food as population and income increase. However, the right incentives must be administered by capable national and agricultural leaders to those who have "to get the job done."

Structure of Agriculture

Hunger and malnutrition, which affect over 400 million people, are caused in part by the unequal distribution of income, resulting in poverty for those who get less than the share required to have a "decent" life. One means to correct for such a malfunction of the distribution system is to simply produce more food.

The technical possibilities to increase food production in the world are tremendous (Blakeslee, Heady and Framingham, 1973; Buringh, van Heemst, and Staring, 1975; de Hoogh, Linneman, Keyzer, and van Heemst, 1976). However, the increase in production will eventually not be derived from the yet virgin lands but must come from increases in yield per acre. Yields in developing countries are generally low compared to their potential. Therefore, within the near future there does not need to be a physical food scarcity. Thus, the threat of a world food problem does not lie primarily in the finiteness of the earth. However, on the other hand, production is bounded by the ultimate finiteness of yields per acre.

Agricultural production

Most of the increase in production has come about because of increased acreage as yields stayed relatively constant. However, since World War II increases in technology have raised yields per acre tremendously in the developed countries and to a lesser extent, yields are increasing in the developing areas. World food production rose 60 percent in the period 1954-1973, 65 percent in the developing countries, and 75 per cent in the developing countries (excluding Asian centrally planned countries). Total grain production (all grains, including rice) rose from 920 million tons to 1,320 million tons from 1961 to 1973. In this period the grain area increased rather slowly from 665 million hectares to about 700 million hectares. Most of this increase was achieved in the first six years. In 1967, however, the major producing and exporting countries changed agricultural policy to reduce grain stocks, resulting in considerable cutbacks in grain areas.[9]

Grain production increased 3.0 percent per annum during the period 1960-62 to 1969-71 at the world level. The grain area increased about

[9] For example, only recently (1976) has the planted wheat acreage in Canada surpassed its 1967 level (U.S. Department of Agriculture, 1976f).

0.4 percent during this period. It follows that high yields accounted for the larger part of the increase in production. Growth rates in area, yield, and production have shown to differ widely between major world regions and individual countries (U.S. Department of Agriculture, 1974 d, p. 14). Japan increased its yield 1.3 percent per annum, while decreasing acreage by 3.5 percent. On the other hand, New Zealand and Australia increased the area by 3.6 percent annually, while their yields only increased 0.2 percent. The developing countries have also experienced considerable increases in grain production. For example, East Asia and East Africa increased production 4.8 and 5.6 percent, respectively. However, most of these increases are attributed to area increases. Thus, although production increases over time in most of the developing countries, the magnitude of the increases is often not large enough to stay ahead of increases in consumption on a per capita basis.

Distribution of crops

Presently, the world has less than 1.472 billion hectares (3.639 billion acres) in production. Of this total, North Central America represents the largest area, 272 million hectares, or 18.5 percent of total arable land. Russia has 232 million hectares, or 15.8 percent. Communist China has 127 million hectares, almost 9 percent of total arable area.

Wheat, rice, and corn are the three major crops cultivated in the world. The total acreage planted to the three crops in 1974 was 478 million hectares, or nearly one-third of total arable land. Wheat is the single most important crop, occupying 225 million hectares. Rice and corn are the next largest crops, engaging 9.3 percent and 7.9 percent, respectively, of the total arable area. Wheat and feed grains are grown mostly in North Central America and Europe. Rice, on the other hand, is the major crop for the developing areas, especially in Central and East Asia, as well as China (Table 2.2).

To increase world food production, agriculture has at its disposal an additional 1.800 billion hectares. Thus, the present 1.472 billion hectares can be increased by 117 percent, as estimated in the work of Blakeslee, Heady and Framingham (1973). According to FAO estimates the costs associated with bringing into production an additional acre of land are between $137 and $312 per hectare (United Nations, 1974a).

Therefore, as population pressures build, recourse can be taken to the yet virgin lands. However, virgin lands are by no means comparable in terms of yields to presently-cultivated soils. If the cropland (1.472 billion hectares) now used for crops were still in ". . . its natural state, it would be vastly less productive than it is today" (Schultz, 1974). Given the yield potentials as obtained from experiment station data over the world, it appears that major efforts should be directed towards increasing yields per acre, especially for those countries that have nearly exhausted the absolute available arable area.

Alternatively, over time agricultural production has partly become less dependent on land. Agricultural technology has decreased the labor/land ratio, while increasing the capital/land ratio. Too, intensive agricultural practices, such as hog or dairy production, are nonland

Table 2.2. Arable land and selected crop acreages in major world regions for 1974[a]

Area	Arable Land	Wheat	Corn	Rice	Potatoes	Sorghum	Soybeans
			(area in thousand hectares)				
Africa	211,287	8,688	18,726	4,463	409	12,945	199
West Asia	60,105	17,461	748	598	270	1,070	25
Central Asia[b]	197,114	28,429	7,465	41,319	625	17,503	0
Eastern Asia	92,520	446	8,223	47,058	486	146	1,772
N.C. America	272,979	36,810	36,056	1,783	744	7,104	21,655
South America	89,380	7,900	17,926	5,383	917	2,972	5,298
West Europe[c]	88,831	16,743	4,102	279	2,263	108	3,018
East Europe	54,402	10,662	7,959	79	4,381	9	287
Oceania	47,187	8,873	70	77	44	573	40
China	127,000	29,001	10,582	35,210	3,792	6	14,335
Russia	232,101	59,700	3,955	500	8,000	90	850
Total	1,472,906	224,713	116,749	21,931	42,562	42,562	47,479

[a] SOURCE: Food and Agriculture Organization, 1974.

[b] Does not include China.

[c] Does not include Russia.

dependent, as is the greenhouse production of fruits and vegetables. If both land and yields ultimately reach capacity, food technology may produce all synthetic food or farmers may produce grain on multi-story hanging gardens. The U.S. Department of Agriculture recently distributed, in the same vein, two publications reflecting some thoughts on agriculture in the next one or two centuries (U.S. Department of Agriculture, 1976b, 1976g).

Factors Affecting Production

Agricultural production depends on many factors. A few of these factors are within control of the producer (acreage planted, fertilizer, timeliness), but most of them are not (weather, prices of outputs, prices of inputs). Governments have often deliberately tried to stimulate agricultural production by manipulating some of the factors of production, such as setting "incentive" price levels to increase production or to adopt technology at a faster pace. Also, the development and adoption of new technologies contributed greatly to increased production. A few of the important factors influencing production are reviewed in this section.

Yields and fertilizer

Yield increases will play a major role in production in the future. Therefore, much research has been directed toward increasing yields through improved, hybrid high-yielding varieties adapted to local conditions. Because of these efforts there has been a yield takeoff--that is, ". . . an abrupt transition from a condition of near static yields to one of rapid, continuing increases" (Brown, 1970). Such a yield takeoff usually leads to increasing profits for millions of farmers, giving strong incentives to others to adopt such new technologies. As is widely observed, however, new high-yielding varieties (HYV) of wheat, corn, or rice do not by themselves lead to great improvements. The Green Revolution which embodies in it the new seed varieties requires a number of additional ingredients before the revolution will come to its logical conclusion. The Green Revolution is based on a package deal. Along with the HYV, the farmers have to apply a number of additional inputs, such as fertilizer, water, weed and pest control, as well as the proper tillage practices. Only if properly executed, yield per acre should increase considerably (Atkinson and Kunkel, 1976).

The Green Revolution, of great significance for the developing areas, has been only partly successful because of lack of one or more of its ingredients. There is a number of reasons for such a lack: 1) supply of fertilizer, pesticides, etc., are inadequate; 2) price of inputs are too high relative to output prices; 3) misunderstanding of the integrated "whole" of the Green Revolution; and 4) other circumstances beyond the farmer's control, such as government policies, droughts, floods, epidemics, but most importantly lack of extension education.

High yields are not obtained by any single element of the package. Indeed, large increases in yield potential will mostly come from interaction effects. Examples of this might be interaction of fertilizer and irrigation with new high yielding varieties or with new tillage practices.

Also, one must be aware that any single input deficiency is the limiting factor for high yields.

Fertilizer usage, which has increased more than five times since World War II, has been the primary yield-increasing input for the last three decades for most crops in the developed countries. The high rates of application in these areas have led to near optimum yields.[10] Thus, variations in the price of either output or input can change the rate of application (Figure 2.1). Further improvement in yield can come from an increase in the percentage of acres fertilized. Too, improvement in overall yield performance can be achieved by distributing fertilizers such that the marginal product is equal for an additional unit of fertilizer across the world. It is calculated that an additional ton of

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[10] The economic optimum yield can be calculated if the price of the output, price of fertilizer, and the responsive curve are known:

$$\P = TR - TC = P_Y Y - \Sigma_j P_{X_i} X_i$$

$$\frac{d\P}{dX_i} = P_Y \frac{dF}{dX_i} - P_{X_i} = 0$$

$$\text{or } \frac{dF}{dX_i} = \frac{PX}{PY}$$

or the marginal product of the input X_i is to be equal to the price ratio of input and output.

Where:

$\P$ = profit;
TR = total revenue;
TC = total cost;
P_Y = price of the output;
P_{X_i} = price of ith input; and
F = the fertilizer response function.

fertilizer in the developed countries would produce an extra five tons of grain. Alternatively, an additional ton of fertilizer in some of the developing areas could produce as much as 15 tons of grain (Brown, 1974; Johnson, 1973).

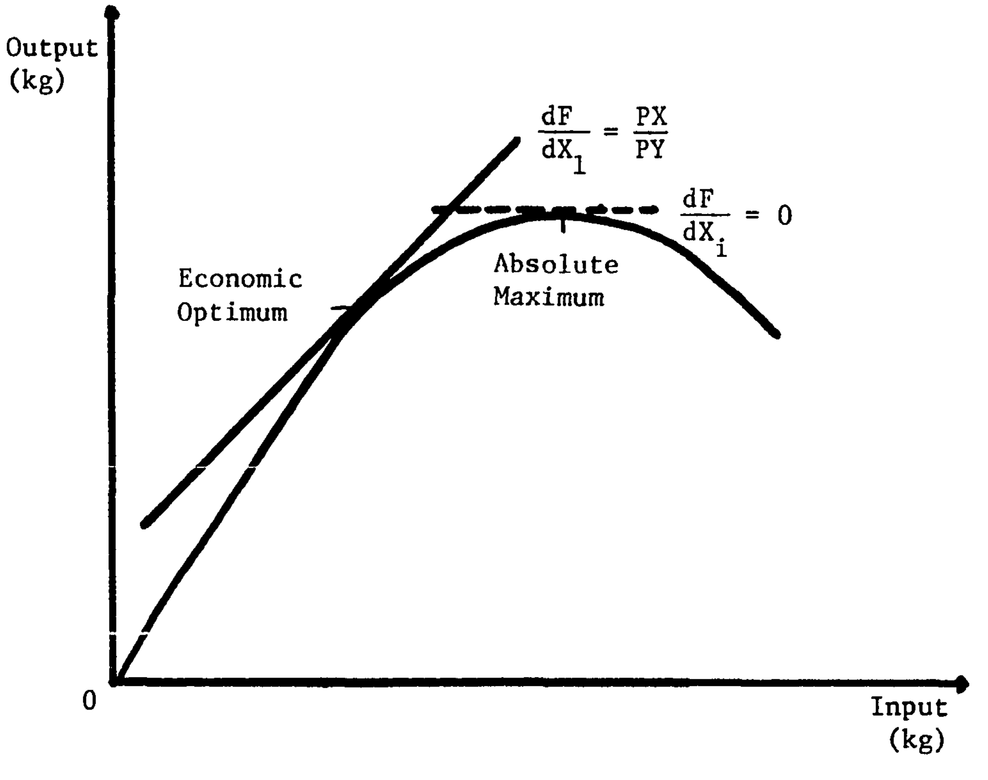

Figure 2.1. Economic optimum yield and maximum yield for any input

After the 1973-74 worldwide fertilizer shortage and resulting high prices, it seems that fertilizer capacity will expand during the remainder of the 1970s. A recent study predicts an excess capacity for the fertilizer industry through 1980-81. This may lead to prices that are somewhat lower than the recent prices (1974), causing increased fertilizer usage through a greater number of acres fertilized and increased rates of application.

Irrigation

Irrigation is a special case of land cultivation. It has vast possibilities for the arid and semi-arid areas and it can greatly increase the production capacity of the soil. As irrigation is applied, production will increase; farm income will rise; and employment will go up. However, water only will not make the crop respond to a maximum. It needs an environment which is in equilibrium with the interactions of the new quantity of water.

Bradfield (1960) stresses the interactions that take place, saying:

> Both farmers and government planners often fail to realize that when you supply plenty of water to a soil-crop complex, you do more than merely add water; you change the effectiveness of every other factor in the system, and consequently, need to develop a new system of management.... A new variety which will give the highest yields under the new moisture regime is needed. New cultural practices are also needed. With plenty of water the plant population can be increased. The rate of fertilization and possibly even the ratio of nutrients in the fertilizer will have to be changed. The weed problems will be different. New crop rotations which will use the land more efficiencly become possible with a dependable water supply.... This list of changes is incomplete but is sufficient to show that when you make abundant irrigation water available to a community, customs developed for generations must be changed. If maximum use is to be made with a minimum of costly mistakes, an experimental farm should be set up in the area, to work out the changes in soil and crop management needed five to ten years before the irrigation water is to become generally available.

Unfortunately, the rate of adaptation has been slow in some countries. There is a number of reasons for this: 1) the rate of return on irrigation projects is generally rather low, especially if the rest of the input prices have stayed constant; and 2) uncertainties in terms of water availability, government policies, etc. (Mellor, 1966).

However, once adapted, irrigation is a major contributor to higher and more stable yields, especially in those areas where rainfall is very unreliable. In many instances, production would be minimal or nonexistent without irrigation. Therefore, this technique may well be the foremost ingredient toward agricultural development for many countries. Table 2.3 gives an indication of the wide adaptation of irrigation in the problem areas. The world's five major irrigating countries, including the People's Republic of China, India, United States, Pakistan, and the USSR, have over 77 percent of the world's irrigated area. Although wheat is a major irrigated crop in the United States and the USSR, rice is the main irrigated crop in India and Asia.

The new HYV of crops, such as wheat and rice, greatly depend on a reliable supply of water. Sufficient water development and timely water control are of primary importance. The lack of either leaves the potential of these new varieties untapped. Improved management is a prerequisite for the successful adaptation of new technology.

<u>Energy</u>

The vital role of energy in food and agricultural production and the consequent importance of adequate energy supplies for the proper

Table 2.3. Major irrigating countries, according to amount of irrigated area[a]

Country	Year[b]	Cultivated area	Irrigated area	Percentage irrigated
		(thousand hectares)		
China	1971 (1960)[c]	127,000	76,000	59.8
India	1972	160,610	31,590	19.7
United States	1969	189,283	15,832	8.4
Pakistan	1973 (1971)	19,385	14,043	72.4
USSR	1972 (1970)	227,500	11,100	4.9
Indonesia	1971	18,100	6,900	38.1
Iran	1971	15,580	5,251	33.7
Mexico	1970	25,776	4,282	16.6
Iraq	1971 (1963)	4,848	3,675	75.8
Egypt	1973	100,145	2,852	2.9
Japan	1972	4,669	2,851	61.1
Italy	1973 (1970)	9,290	3,345	36.0
Spain	1973	16,054	2,736	17.0
Thailand	1971 (1972)	12,431	2,476	20.0
Argentina	1968 (1959)	23,851	1,555	6.5
Turkey	1973 (1972)	25,543	1,939	7.6
Australia	1973 (1972)	45,011	1,689	3.8
Chili	1973	5,480	1,238	22.6
Peru	1973	2,558	1,110	43.4
Bulgaria	1973	4,120	764	18.5

[a] SOURCE: Food Agriculture Organization, 1974.

[b] "Year" refers to the most recent data of irrigated acres.

[c] SOURCE: Food and Agriculture Organization, 1974.

functioning of the food systems are obvious. It is, for example, estimated that 12 percent of total energy is used in food production and related industries. Of this amount, 24 percent is consumed directly or indirectly in farm production, 39 percent in transport and processing, and 37 percent is used for refrigeration and cooking (Steinhart and Steinhart, 1974).

Energy from a wide range of sources is at some point involved in the food production system. The major renewable resource of energy is the sun. Solar energy provides sufficient calories to produce a food crop every year and may soon find its way into domestic uses, such as heating and refrigeration. In crop production it is estimated that solar energy provides by far the most kilocalories (KCAL) compared to those supplied by fossil fuels (Pimental, 1973).

The more conventional sources of energy are directly or indirectly used as inputs to agriculture; i.e., electrical power for motion or heating, natural gas, diesel and other fuels.

The recent energy crises have had some effect on agricultural production and consumption. The record-high prices of the last two years[11] may act to reduce output and increase food prices, ceterus paribus. However, recent research indicates that the demand for energy is rather inelastic. Thus, it is found that if American agriculture is faced with

[11] Crude oil prices in 1973-74 increased as much as 400 percent over those of the previous years.

high energy prices, demand for energy is estimated to decrease 5 percent and reduce output little (Dvoskin, 1976).[12]

Because of the high price of crude oil, derivatives of the product also increase in price. Thus, prices of fertilizer and pesticides are also raised, leading to a proportional increase in production cost, and a decreased demand for the farmer's output. However, given the inelastic nature of the demand for food, the farmer's income may increase.

The impact of higher prices for these nonfarm-produced inputs is not affecting all countries and commodities evenly. The production of corn differs widely in energy use per acre from hay. Also, the level of technology employed determines how energy-intensive agriculture is. Thus, the energy squeeze has had a greater impact on the U.S. farmer compared to an Indian village farmer using animal power and some fertilizer. Also, the nature of crops determines energy use. For example, soybeans require little or no nitrogen, whereas corn uses great quantities of it. Thus, the relative importance of fertilizers, fuels, and pesticides among total energy inputs varies widely among countries and commodities (Pimental, 1973).

In modern agricultural systems the amount of energy now used to produce food exceeds several times the amount of food energy that the crops themselves yield. Because most of the presently known energy sources are nonrenewable, countries reexamine their energy price policies. Nonetheless, food production must drastically increase in the years

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[12]The energy price is calculated on a per KCAL basis. Under the high energy alternative, the price per unit of energy, KCAL, is doubled.

ahead, and this can best be accomplished if resources and inputs are put to use there, where they yield the highest marginal product. It may be more profitable for the world as a whole that the developed energy-intensive countries move back on their response curve, applying the inputs saved toward those areas where the marginal increase of a unit of energy is much higher.

Weather

Annual fluctuations in production are a major cause of the world food crises. Research has indicated that weather effects are in general not offsetting; e.g., a 25-region study, across the world, shows a positive correlation among yields in the same crop year (U.S. Department of Agriculture, 1974d). This leads to the conclusion that major crop failures would occur simultaneously; e.g., the crops of 1964-66, 1972, and 1974. The result of such failures has serious implications not only for the countries affected but also for the world as a whole. Consequently, in planning world food policy, account must be taken of the weather situations across the world (Table 2.4).

The little ice age

A number of recent scientific articles suggest that the world is in the process of a change in climate (Thompson, 1976). These studies claim that a weather cycle exists that will cause a change in the average long-run temperature 2 to 3 degrees and vary the hours of sunlight in a particular region. Scientists believe that the planet Earth has moved into the down phase of the cycle (Bryson, 1974; Thompson, 1976; and Willett,

Table 2.4. Changes in grain production because of weather in 25 major world grain-producing regions[a]

Grain	Without Covariation	With Covariation	Percent Difference
	(thousand metric tons)		
Wheat	11.59	13.28	+15
Rice	4.58	4.81	+ 5
Corn	5.68	6.24	+10
Barley	5.13	5.42	+ 6
Oats	1.95	2.23	+14
Sorghum-Millet	2.06	2.23	+ 8
Rye	0.91	1.03	+13
Coarse-grain(mid rye)	8.22	10.04	+22
All grains(incl. rice)	14.74	21.08	+43

[a] SOURCE: U.S. Department of Agriculture, 1974d.

1975). This phase by itself can last 200 years and is also known as the "little ice age." The result of a continuing cooling trend is that the variability in climatological variables such as rainfall and temperatures usually increases. Also, a cooling trend tends to shorten the growing season and decreases production in the higher latitude countries; e.g., Russia and Canada. To regions closer to the equator such a trend also has detrimental effects, because cool polar air will push the monsoon belt closer to the tropical rain belt, causing the absence, or highly irregular occurrence of monsoons in the subtropical monsoon belt. The region between the 30th and 50th latitudes of the earth in the northern hemisphere stands to gain somewhat from a cooling trend. Studies indicate that winter wheat, corn, and soybeans would benefit from somewhat cooler and drier conditions (Thompson, 1975; 1976). However, a cooling trend in general is regarded as a less-than-favorable change. If weather conditions again should deviate from normal from now until 2000 as much as during the 1890-1955 period in the corn and soybean belt, average yields would drop about 3 percent.

Regardless of whether or not the "little ice age" is on its way (similar to those experienced during the 15th and 17th centuries), attention must turn to other relationships that exist among the various meteorological variables.

Sunspots

One of the latest popularized concepts, although long discovered, is the sunspot theory.[13] Although so far void of explanatory relationships underlying the solar activity, this theory, over its 130-year life, has accumulated evidence ". . . so compelling that it is no longer possible to deny the existence of strong connections between the weather and radiation changes associated with a whole range of solar phenomena" (King, 1976). It seems that the number of sunspots on the face of the

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[13] The "sunspot theory" derives its name from the dark spots that occur in some fashion on the face of the sun. They can be spotted with the bare eye and appear with some frequency in large or small groups, depending upon the solar activity.

sun increases and decreases in some cyclical fashion that usually lasts between 9 and 14 years but most regularly between 10 and 11 years. The 10-11 year cycle translates into a 20-22 year cycle when every other cycle is plotted negatively. This derived 20-22 year cycle corresponds almost exactly with a July temperature cycle in the Great Plains of the United States (Thompson, 1976). Indeed, the sunspot cycles and their coincidence with drought years are reason to investigate the cause-effect relationships. Palmer indicated in 1964 that ". . . the apparent regularity (of serious droughts during 1894, 1913, 1934, 1954) leads one to speculate concerning the possibility that a drought of extreme severity will again occur in western Kansas sometime around the mid-1970s" (Palmer, 1964). The low sunspot activity usually associated with drought periods occurred early in 1976 and severely damaged the winter wheat crop in this region.

The relatively short period over which reliable data has been collected prevents one from testing the apparent relationship between solar activity, weather data, and yields. However, since droughts have occurred fairly regularly over the past 100 years or so, development of the cyclical relationships must be researched further.

As meteorological information is gathered across the world on a regular basis, the need for cooperation on weather-related issues is growing. Institutions are created which aid in keeping record of world weather patterns and their changes over time. World Weather Watch, the World Meteorological Organization, and the World Agrometeorological Watch are organizations that attempt to coordinate data, relay weather situations, and make weather forecasts 2-4 days ahead, etc.. In particular, the latter organization is of interest because it will specialize in studying weather situations in relation to agriculture. Agrometeorology, if applied at national, regional, and world levels, would greatly help agriculture and help increase world agriculture production. A world weather watch must basically act as a warning system of agricultural crop conditions across the world so that corrective steps can be taken as soon as possible. Also agrometeorology ought to extend into areas such as predicting crop diseases, insect plagues, etc., such that preventative measures can be taken. However, the lack of adequate facilities in most countries does not at this time lend itself to such a sophisticated network. However, it can be said that a successful agrometeorological institute would tremendously help world food production.

Demand for Agricultural Products

The demand for food depends upon a number of variables (population and income growth, the level of income, and income distribution). These variables will be briefly presented and analyzed in terms of the influence they have on consumption.

Population growth

Total world population was 3.6 billion in 1970 (United Nations, 1974a). In 1973 it was estimated to be 3.8 billion (U.S. Department of Agriculture, 1974d), and in 1980 it is projected to be 4.2-4.6 billion. It is estimated that annually an additional 70 to 80 million people must be fed. The current growth rate is about 2.0 percent, but it differs widely among the developed and developing countries. The Demographic Yearbook indicates that developed countries have very low or even negative growth rates, whereas on the other hand, a number of developing countries have rates well over 3.0 percent; i.e., El Salvador, Libya, Nicaragua, etc. (World Bank, 1973). The impact of such growth rates on population numbers can be illustrated as follows. A country that has a growth rate of 1 percent will double its population every 72 years. On the other hand, a country that has a growth rate of 3.5 percent will double its population every 20 years.

Although agricultural production of developing countries has grown as fast or faster than that of the developed nations, the high rate of population growth hinders an adequate development of per capita food supplies without the help of imports, Table 2.5. The developing countries have 70 percent of the world's population and account for 86 percent of the annual increase. It is, therefore, not difficult to see that the food shortage may get worse before it gets better.

Table 2.5. Rate of growth of food production in relation to population, world and main regions, 1952-62, 1962-72, and 1974[a]

Region	1952-62			1962-72		
	Population Growth	Food Production		Population Growth	Food Production	
		Total	Per Capita		Total	Per Capita
			Percent Per Year[b]			
Western Europe	.8	2.9	2.1	.8	2.2	1.4
North America	1.8	1.9	.1	1.2	2.4	1.2
Oceania	2.2	3.1	.9	2.0	2.7	.7
Eastern Europe and U.S.S.R.	1.5	4.5	3.0	1.0	3.5	2.5
Total Developed Countries[c]	1.3	3.1	1.8	1.0	2.7	1.7
Africa	2.2	2.2	-	2.5	2.7	.2
Far East	2.3	3.1	.8	2.5	2.7	.2
Latin America	2.8	3.2	.4	2.9	3.1	.2
Near East	2.6	3.4	.8	2.8	3.0	.2
Asian Centrally Planned Economics	1.8	3.2	1.4	1.9	2.6	.7
Total Developing Countries	2.4	3.1	.7	2.4	2.7	.3
World	2.0	3.1	1.1	1.9	2.7	.8

[a] SOURCE: United Nations, 1974a.

[b] Trend rate of growth annually compounded.

[c] Including countries in other regions not specified.

Income and income elasticities

Population growth is not the only factor that determines the quantity demanded. Income growth exerts considerable influence on demand. In general, as income increases through time, demand will increase proportionately. Thus, it is found that per capita consumption of grains makes up a large portion at the lower levels of income. When income increases enough to allow for other than mere staple food, direct grain consumption decreases slightly. However, at this higher level of income indirect per capita consumption of grain increases because of an increase in consumption of eggs, milk, poultry, and most importantly, grain-fed beef (Figure 2.2). As income grows the proportion spent on food decreases; e.g., the proportion of income spent on food in the developing nations is over 50 percent, whereas it is only about 20 percent in most industrialized countries.

The national income, whether it is on a per capita basis or in terms of gross domestic product, does increase rather smoothly over time. In the developed countries growth of income is almost the only source of increases in consumption, while on the other hand, the developing nations' increase can be contributed to a growing population.

Of course, one must also take into account the price effect, especially in the developed regions. The rather low grain prices in the 1960s and early 1970s led to an increase in demand for livestock products in the developed nations. Feed grains did not then compete directly with food grains of the developing nations. This situation, however,

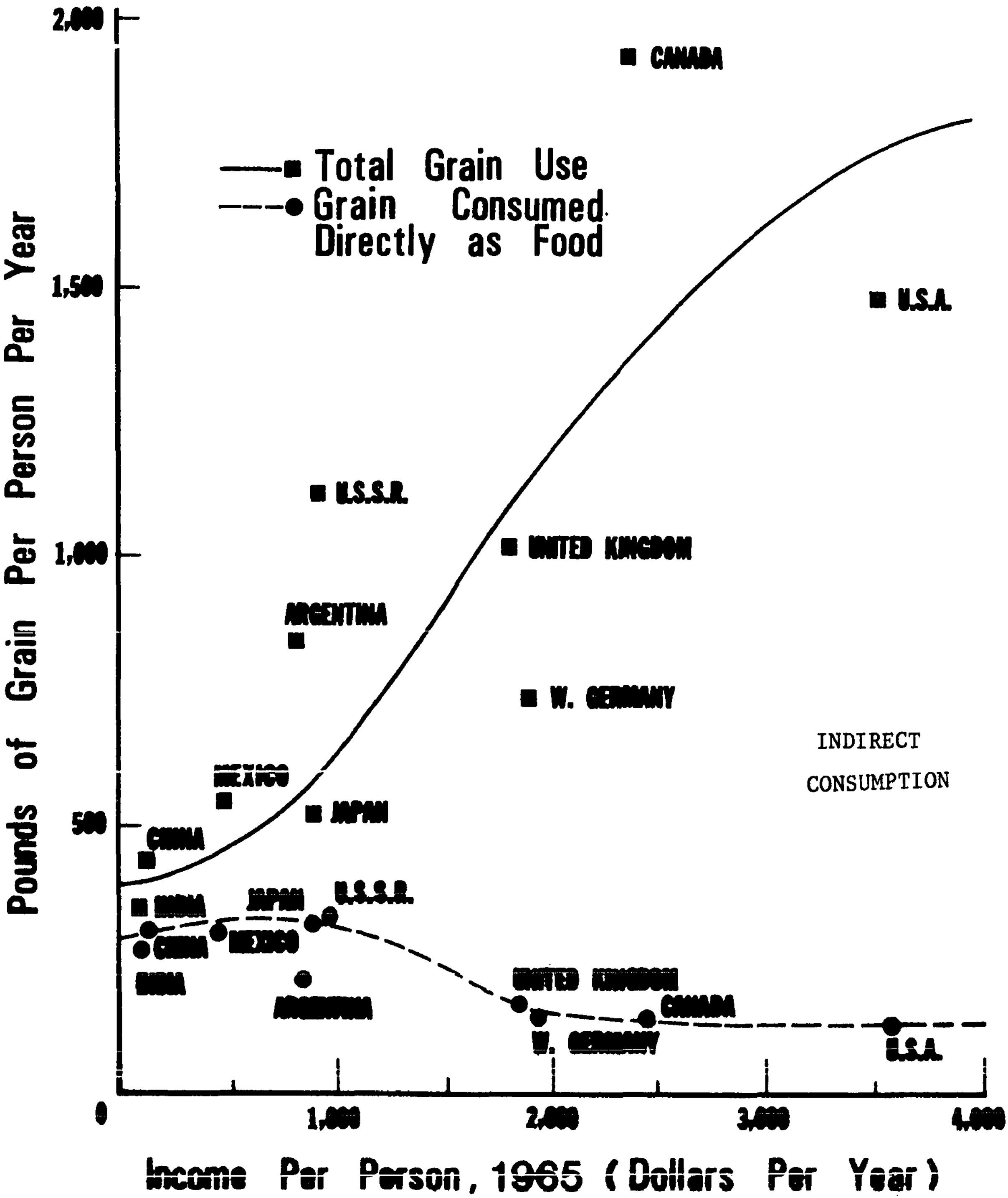

Figure 2.2. Direct and indirect grain consumption by per capita income, selected countries.

reversed after 1972. Since that time the competition for grain for food and feed between developing and developed regions has been one of "life or meat."

Directly related to income is the distribution of income. It is generally acknowledged that the distribution is more skewed in the developing nations than in the industrialized areas (U.S. Department of Agriculture, 1974d). Moreover, the level of income in the latter countries is such that the food consumption pattern is not greatly affected by a redistribution. However, in the developing areas it is found that as the country has a lower per capita income, the distribution is more unequal; e.g., a country with a per capita income of \$100-\$200 has a more unequal distribution than the country in the \$200-\$300 bracket, etc. (Figure 2.3). For example, in countries that belong in the \$200-\$300 income bracket, the top 5 percent of income recipients lay claim on almost 70 percent of Gross Domestic Product. Successively higher income classes show much less pronounced income differences. The effect of this is, of course, that at the lower income level the effects of an increase in income on food consumption is quite different that at higher levels of income (Table 2.6). In the low income countries, where per capita incomes are below the \$200 level, future increases in income will be used foremost for increases in cereal and other staples (World Bank, 1973). It is estimated that about 2 billion people currently belong in the \$200 income bracket. It cannot, therefore, be expected that any great shifts in income distribution will take place in those regions. Increased demands on the grain-exporting capacities of the surplus-producing nations will be made in the next one or two decades, reiterating the need for a strong

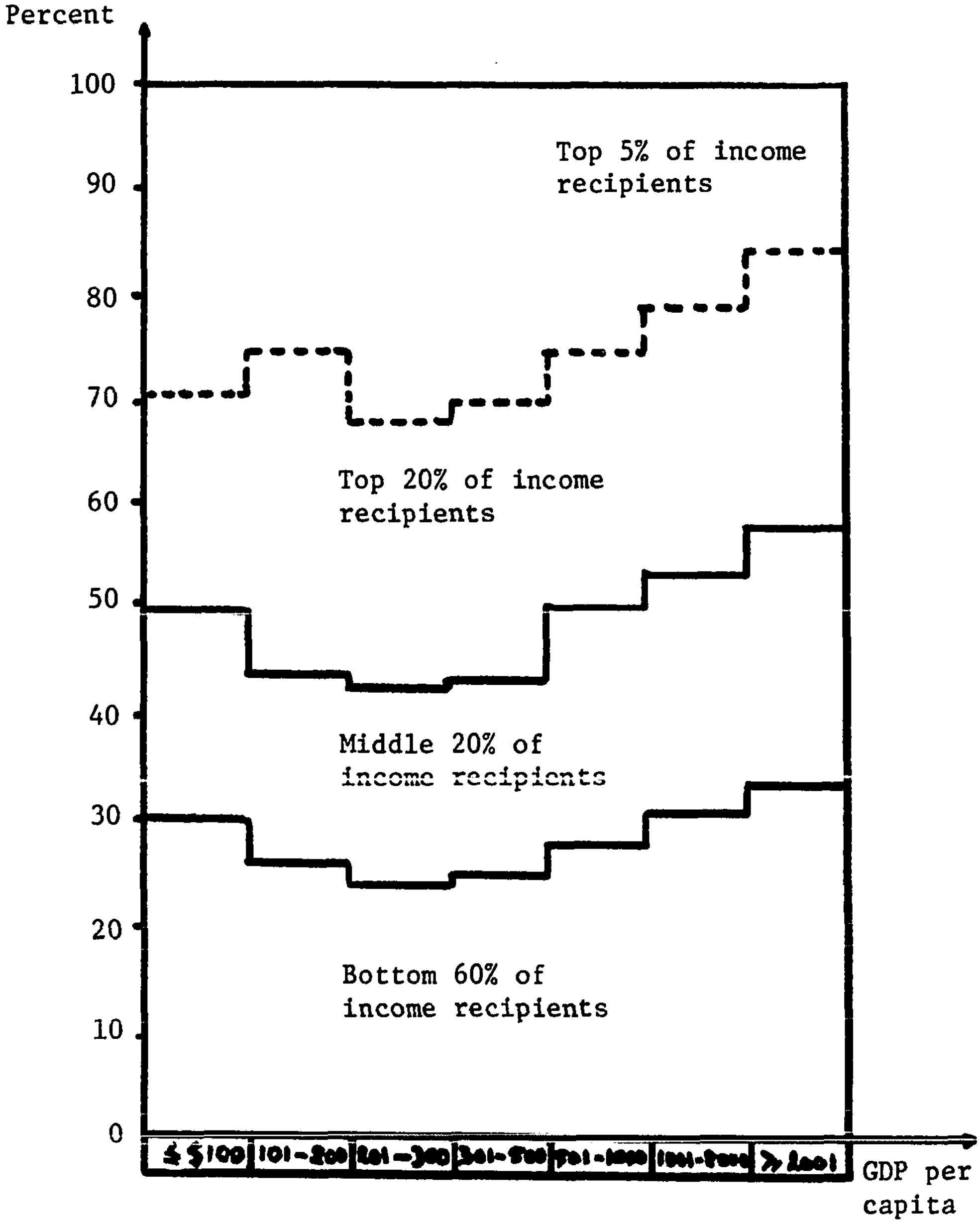

Figure 2.3. Distribution of income at different levels of per capita GDP (Gross Domestic Product) (Paukert, 1973)

Table 2.6. Indicators of size distribution of income (average for groups of countries)[a] (Paukert, 1973)

Gross Domestic Product per head (US$)	Number of countries	Quintiles 1st (lowest)	2nd	3rd	4th	5th (highest)	Top 5%	Bottom 40%	Bottom 60%
		(percent)							
Below 100	9	7.0	10.0	13.1	19.4	50.5	29.1	17.0	30.1
101-200	8	5.3	8.6	12.0	17.5	56.5	24.9	13.9	25.9
201-300	11	4.8	8.0	11.3	18.1	57.7	32.0	12.8	24.1
301-500	9	4.5	7.9	12.3	18.0	57.4	30.0	12.4	24.7
501-1,000	6	5.1	8.9	13.9	22.1	50.1	25.4	14.0	27.9
1,000-2,000	10	4.7	10.5	15.9	22.2	46.6	20.9	15.2	31.1
2,001 and above	3	5.0	10.9	17.9	24.1	42.7	16.4	15.9	33.8

[a]NOTE: First quintile represents the percentage of total personal income received by the poorest 20 percent of income recipients; the second quintile represents that received by the next 20 percent.

market institution but also a distribution policy which to some extent will shield the poor food-deficit nations from the violent gyrations of the world market.

Elasticities of demand

The income elasticity of the demand for food differs widely among various levels of income within and among regions. The income elasticity for food is expected to be higher in the developing regions compared to the developed nations because of the different levels of income. Thus, one would expect a poor nation to purchase a greater proportion of food out of an additional dollar of income than an affluent nation would. Table 2.7 indicates that the elasticities differ between nations; e.g., India vs. the United States. Indeed, as the affluence increases, income elasticities may become negative, indicating that for additional increases in income, the quantity demanded of that commodity would diminish, if relevant prices remain constant.

Trade and stocks

Patterns of international trade tend to reflect the economic structures of the countries involved. They indicate which countries are exporters or importers for a particular commodity and what institutional barriers may exist. Overall, indications are that the developing areas will increase their imports for food and feed grains for an extended period (Table 2.8). This means increased imports will continue to bring pressure on the countries' foreign exchange funds. Balance of payment problems are already encountered in

Table 2.7. Representative income elasticities for selected foods and selected countries[a]

Food	India	Brazil	Japan	Australia	EC	United States	World
Wheat	.50	.40	.10	-.10	-.32	-.30	-.24
Rice	.40	.20	-.10	.00	-.11	.20	.23
Maize	-.10	-.30	-.50[b]	.00	-.12	-.10	.10
Sugar	1.03	.09	.39	-.10	.31	.10	.29
Fruits	.80	.49	.57	.71	.58	.25	.55
Meat	1.17	.48	.79	.07	.48	.24	.32
Fats & Oils	.92	.68	.40	.05	.13	.01	.22
Total	.43	.19	.13	.02	.08	-.01	.10
Farm value	.57	.34	.28	.11	.25	.04	.19

[a]SOURCE: Food and Agriculture Organization, 1971.

[b]Coarse grains.

Table 2.8. Imports of wheat and feed grains of major world regions for the 1965-1974 period[a]

Year	Wheat			Feed Grain		
	Africa	Asia	South America	Africa	Asia	South America
	(metric tons)					
1965	4,116,700	22,311,000	3,725,600	481,640	5,285,600	140,930
1966	5,421,300	24,206,600	4,605,600	910,250	4,909,680	162,360
1967	5,984,800	21,564,100	4,536,100	522,890	5,855,050	120,050
1968	5,903,600	22,501,300	5,052,100	309,600	7,382,150	283,310
1969	4,002,653	19,059,624	4,637,674	406,308	8,136,968	503,708
1970	4,548,969	23,971,531	4,057,331	632,839	9,307,640	553,827
1971	6,271,879	22,603,690	4,306,172	837,803	9,124,223	648,482
1972	5,923,231	21,291,628	4,397,950	676,302	11,965,828	392,836
1973	7,191,133	27,590,884	6,028,888	635,302	15,184,271	1,015,132
1974	7,800,420	28,962,559	5,513,224	1,350,373	14,834,623	951,775

[a]SOURCE: Food and Agriculture Organization, 1972; 1974.

many countries because of increased prices of fuel and fertilizer during recent years, in addition to servicing existing debt.

Import policies have changed from those in the 1960s. During that period in some countries food imports were restricted when domestic supply was short. Domestic governments would apply import taxes, restrict physical imports on a compulsory basis, or establish a quota for the particular commodity. Furthermore, if domestic grain production was low, compulsory livestock slaughters would bring about a shift in feed grains utilization. Thus, a combination of increased prices and shifts in deman would usually tide the nation over. This attitude has changed. Consumer awareness makes it difficult to apply these same techniques, and thus, countries have recently changed to purchasing grain in anticipation of deficits; e.g., the infamous "Russian wheat deal."

The volume of grain imports during most of the 1960s generally provided a poor indication of production capacities in the importing nations. Large carryover stocks and low prices in the surplus-producing nations led to large quantities imported by deficit nations.[14] Because of the favorable grain/beef price ratio, livestock demand for grain made up an important part of foreign total demand. However, recent events have reversed this situation, leading to the agricultural price index increasing by more than 50 percent since 1972-73. Differential inflation rates have also affected world trade as well as a series of currency

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[14]Some scientists partly blame the current food situation on the large noncommercial aid shipments, thereby depressing domestic prices that took place in the 1960s.

devaluations vis-a-vis gold. On a worldwide basis, trade increased more rapidly during recent years (Food and Agriculture Organization, 1975) in value terms as well as physical terms. In particular, increases in the volume of coarse grains and wheat have greatly increased. The volume of trade has increased since World War II, with the developed countries accounting for most of the increase. The recent spurt in trade accentuated the dominant position of the developed countries vs. the developing and centrally-planned countries. The developed countries accounted for 64 (61) percent of total trade, developing countries for 29 (32) percent, and the centrally-planned countries for 7 percent in 1974 (Food and Agriculture Organization, 1975).[15]

Most countries have been hurt by the extreme fluctuations and steep rises in grain prices. Grain stocks, which had accumulated during the 1960s and early 1970s, fell sharply after 1972. Continued strong demand and crop failures depleted world stocks of wheat and feed grains considerably in 1973 and even further in 1974. Mackie analyzed these impacts of short supplies of grain on prices, in particular for wheat. One of his findings is that the price of wheat is very strongly related to the level of reserves. Mackie writes ". . . there may be some critical level of stocks in relation to export demand. The critical or threshold level of stocks to exports for triggering a price change is about 50 percent or six months' free world reserves" (Mackie, 1974).

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[15] Figures in brackets represent the 1972 relative shares of world trade.

It is for this reason that sensible reserve policy alternatives, those that carry the greatest benefit to society as a whole, must be developed.

CHAPTER III. AMERICAN AGRICULTURE: FACTORS AFFECTING SUPPLY AND DEMAND

American agriculture has undergone and is still undergoing dramatic changes. Total production and productive capacity have increased considerably over the past three decades although the number of farms and the number of farm workers have decreased. The number of farms has declined by 69 percent to 2.286 million farms, while the average size of farms has increased 34 percent to 385 acres since 1959 (Table 3.1). Further, the number of persons employed in agriculture decreased by nearly 3 million during the 1959-1974 period (U.S. Department of Agriculture, 1974a).

Economic Development

These rapid changes are a result of pressure brought on by economic development. "Economic development is a process by which a population increases the efficiency with which it provides desired goods and services, thereby increasing per capita levels of living and general well-being (Mellor, 1966, p. 3). Under this process, the relative prices and productivities of inputs change in the direction of that input which produces most output for a given input; i.e., agriculture may favor capital inputs over labor. Some of these capital inputs substitute directly for labor, such as machinery and power. Other forms of capital substitute more indirectly for labor as in the case of biological inputs; e.g., hybrid seeds, fertilizer, and pesticides. And whereas the former method of substitution results in greater land/labor and animal/labor ratios, the latter leads to the biological inputs that produce more output per unit of input.

Table 3.1. Number, average size of farms, and farm employment in the United States, 1959-74[a]

Year	Number (thousand)	Average Size (acres)	Employment (thousand persons)
1959	4,105	288	7,342
1960	3,963	297	7,057
1961	3,825	305	6,919
1962	3,692	314	6,700
1963	3,572	322	6,518
1964	3,457	332	6,110
1965	3,356	340	5,610
1966	3,257	348	5,214
1967	3,162	355	4,903
1968	3,071	363	4,749
1969	2,999	369	4,596
1970	2,954	373	4,523
1971	2,909	377	4,436
1972	2,870	381	4,373
1973	2,844	383	4,337
1974	2,830	384	4,313
1975[b]	2,819	385	

[a] SOURCE: U.S. Department of Agriculture, 1975a.

[b] Preliminary

Technological change

A major factor contributing to economic development is development and adoption of new technology. Technological change interacts greatly with labor and capital. The result of technological change coult be capital-using, neutral, or labor-using technology being adopted by the agricultural industry (Henderson and Quandt, 1971).

Development of technology and the subsequent adoption of it have been functions of agricultural stimuli administered through appropriate policies. Such policies have been frequent in the United States. Some of these policies will be reviewed later in this chapter.

Farm output increased 93 percent during the 1939-73 period (Tables 3.2 and 3.3). Over time there has been a steady increase in output while the number of farms and farm workers steadily declined. Total inputs, however, have not changed very much and the improvement in quality of inputs because of new technology is difficult to discern, except in the output/input ratio (Table 3.2). This ratio most closely exhibits the effects of the technological change that has taken place on the American farm. As further evidence of this trend, Table 3.4 separates out some of the farm inputs. Farm labor decreased 69 percent from its 1939 level. During the farm exodus other inputs were substituted. Thus, mechanical power and machinery increased more than 2.5 times above 1939 levels. Early in this period rural electrification and conversion from animal power to motor power was completed. Biological inputs such as fertilizer, lime, and pesticides increased more than 900 percent from the 1939 level and 100 percent since 1963.

These rapid and dramatic changes have left agriculture somewhat in disarray. Some rural communities see themselves regressing in terms of value of sales, employment, and, consequently, quality of life. The farm laborer has had to change from farm work to industrial-type employment and often has had to leave the rural area altogether. Even as this

Table 3.2. Indices of farm output, farm input, and output per unit of input, 1967 = 100[a]

Year	Farm Output	Total Input	Output/Unit Input
1939	58	97	60
1940	50	98	61
1941	62	98	63
1942	69	101	69
1943	68	102	67
1944	70	103	68
1945	69	100	69
1946	71	99	72
1947	69	99	70
1948	75	100	75
1949	74	102	73
1950	73	101	73
1951	75	104	73
1952	78	104	76
1953	79	103	77
1954	79	102	78
1955	82	102	80
1956	82	106	82
1957	80	97	83
1958	86	97	89
1959	88	98	90
1960	90	97	93
1961	90	96	94
1962	91	97	95
1963	95	97	98
1964	94	98	96
1965	97	98	99
1966	96	99	97
1967	100	100	100
1968	102	101	101
1969	103	102	101
1970	102	102	100
1971	111	101	110
1972	110	101	109
1973	112	102	110
1974	106	101	104

[a]SOURCE: U.S. Department of Agriculture, 1975a.

Table 3.3. Measures of productivity for United States 1950-1974[a]

	1950	1955	1960	1965	1970	1971	1972	1973	1974
Crop production per acre of cropland	100	107	128	145	150	162	167	167	150
Farm output per hour of labor	100	132	191	262	329	371	379	391	379
Farm output per unit of non-purchased input	100	116	155	182	231	238	239	243	225
Crop output per unit of total farm nutrient and pesticide	100	69	60	43	37	37	35	34	31
Crop output per horsepower of tractors	100	83	75	70	64	67	66	66	60
Farm output per unit of mechanical power and machinery	100	97	104	105	116	127	128	126	116
Farm output per unit of purchased input	100	90	91	100	89	97	95	96	93
Farm output per unit of all inputs	100	111	128	137	138	152	150	151	145

[a]SOURCE: U.S. Department of Agriculture, 1975c.

Table 3.4. Indices of input usage in American agriculture, 1939-1974, 1967 = 100[a]

Year	Total Inputs	Farm Labor	Mechanical Power and Machinery	Fertilizer and Lime
1939	97	270	40	12
1940	98	269	42	14
1941	98	265	44	15
1942	101	271	50	17
1943	102	267	53	19
1944	103	265	55	23
1945	100	249	56	23
1946	99	239	55	24
1947	99	226	60	28
1948	100	220	68	29
1949	102	212	75	31
1950	101	199	79	32
1951	104	200	84	36
1952	104	191	88	39
1953	103	184	90	42
1954	102	176	90	43
1955	102	170	91	45
1956	100	160	91	44
1957	97	149	90	46
1958	97	143	91	48
1959	98	139	92	50
1960	97	134	91	50
1961	96	129	90	54
1962	96	123	91	59
1963	97	120	92	66
1964	98	115	93	72
1965	98	109	96	77
1966	99	101	100	86
1967	100	101	100	100
1968	101	96	102	106
1969	102	94	103	110
1970	102	89	102	110
1971	101	89	100	120
1972	101	85	99	126
1973	102	85	102	133
1974[b]	101	83	105	138

[a]SOURCE: U.S. Department of Agriculture, 1972; 1975c.

[b]Preliminary.

process has occurred and is still occurring, agricultural adjustment has been too slow to give the farmer an income from agriculture that is at par with that of other industries. The flow of farm laborers out of agriculture will continue for many years to come. The lower bound on the number of people related to and working in the agricultural sector is set by the pace of economic development and public policy.

Economic development does not just happen. The economic system needs stimuli to obtain momentum. The American economy has been one in which incentives and stimuli prevailed from the early days of settlement. As the continent was getting settled some 200 to 300 years ago, a number of forces acted to induce change in agriculture. One of these forces was the federal government through its legislation. In dealing with commercial agriculture, the government enacted legislation at various times to support or subsidize the agricultural sector when it needed it.

Public policies

Public policies toward agriculture have been mainly directed toward price and income stabilization. On the other hand, however, other policies also were devised to keep real food prices low for the consumer.

Public policies can be divided into two categories. The first category may be called "development" policies. The second may be called "compensation" policies (Heady, 1962).

Development policies are policies that in one way or another have contributed to the development of agriculture. Perhaps Jefferson set the stage for the importance that agriculture was to play in American economic development. He placed high value on social and political stability and believed that the farming communities could contribute toward these goals. He believed in family-type farms, which in his mind were the basic foundation of the democracy. Indeed, Jefferson wrote: "Generally speaking the proportion which the aggregate of the other classes of citizens bears in any state to that of its husbandsmen is the proportion of its unsound to its healthy parts and is good enough a barometer whereby to measure its degree of corruption" (Hathaway, 1963, p. 62).

These beliefs in a strong and productive agriculture, then, were the philosophy of the policy makers. Most of the legislative acts passed were of such a nature that they would stimulate growth in agriculture. The Homestead Act of 1862 allowed for homesteading in the as yet unsettled areas west of the Mississippi River. Under this act settlers could buy a prespecified unit of land at a set price. Also passed in 1862 was the Morrill Act. This act established low cost education at the agricultural land grant colleges in each of the states. The Hatch Act of 1887 and the Smith-Lever Act of 1914 provided for agricultural experiment stations and extension services within the land grant colleges. These acts have provided the incentive to look for better and more efficient ways to produce the nation's food and fiber. Such research and extension work in the early 20th century could only be accomplished at colleges where state and federal funds were available. The Reclamation Act in 1902 provided funds for and institutionalized the Bureau of Reclamation. The act established funds to develop irrigation projects in the western United States. In 1916 the Federal Farm Loan Act was passed and provided for an increase in "soft" loans for the farm industry. This act was passed during World War I, when large food deficits developed in the countries that were at war.

Finally, the Smith-Hughes Act, passed in 1917, established vocational-agriculture programs in high schools. The impact of such a law can be easily imagined: grass-root-level development of the young farmer to learn new methods and techniques and to become familiar with the research being undertaken at the agricultural research stations.

The settlement of the West soon after the turn of the 20th century was virtually completed at the same time as the Industrial Revolution. Industries were established and were now bidding away farm labor from the rural areas.[16] This led farmers to substitute capital for labor. As the price ratios were such that it was beneficial to maintain a large land-labor ratio, the wage level and the price of capital were such that the capital-labor ratio must also increase.[17] This set of changes eventually led to an ever larger land-man ratio and a continuing substitution of capital for labor. Additionally, to lower the per unit cost of production, the farm units were enlarged.

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[16] What has happened in most other countries is the continued breaking up of family farms into increasingly smaller units because of an increasing population and inssuficient industrialization. This then led to the intensive agriculture that can now be found in much of Europe, Latin America, and Africa.

[17] Not only were wages bid up, but capital became increasingly cheaper because of new technologies that were rapidly developed.

Around the 1920s both the public and private sectors began to get involved in developing and disseminating new technology. The technology came in many forms (education, new machinery, electrical power, etc.). By the time of the Depression in the early 1930s the United States had attained a relatively high level of economic development with all consequences thereof.

With the adopted technology, output increased faster than demand, leading to glutted markets, depressed farm prices, and low incomes. Compensation policies were developed to deal with this situation. Compensation policies were typically designed to temporarily relieve the farm industry from its burden of overproduction, low prices, and low incomes Even though such policies were to relieve the price-income situation on the farm, they were in many instances at the same time development policies and thus, somehow worsened the situation that they were created to improve. Ironically, some of the development policies were also still in force, e.g., the Hatch and Smith-Lever Acts. The result of this was that throughout most of the following four decades agriculture was burdened with overproduction and underpayment.

These compensation policies, which were in the form of price supports and acreage diversion payments, were first devised and passed in 1933 after a futile attempt had been made in 1929 with the creation of the Agricultural Marketing Act.[18] The Agricultural Adjustment Act of 1933

[18] Most of the data in this section were obtained from a recent publication, "A Short History of Agricultural Adjustment, 1933-75" (Rasmussen, Baker, and Ward, 1976).

(AAA) was to restore the agricultural purchasing power via (1) voluntary reduction of acreage for a number of crops, (2) regulated marketing, (3) licensed processors of agricultural products, and (4) processor taxes for creating a strong market institution. The commodities for which this act was passed were split into basic and nonbasic commodities. The goal was to restore a parity price level based on the situation as it existed in 1910-14 on a "prices received-prices paid" basis. The 1933 act, however, was ruled illegal in 1936. The Roosevelt administration, which had drawn up the compensation policy, also designed the Soil Conservation and Domestic Allotment Act in the same year. This act was to promote soil conservation, efficient use of agricultural resources, and maintain income. The latter policy goal was different from the 1933 AAA Act. Income parity, instead of price parity, was to be maintained.

The Agricultural Adjustment Act of 1938, which replaced the failing 1936 Conservation Act, combined the conservation program of 1936 with new features designed to combat drought emergencies as well as income and price crises. Mandatory, nonrecourse loans, as well as marketing quotas, referendums, crop insurance and parity payments (up to 50-75 percent of parity) were established for some of the major crops.

Another goal was to protect the consumer to some extent through maintenance of adequate reserves of food, feed, and fiber. It was this idea that led to Agriculture Secretary Wallace's concept of the "ever-normal granary."

After World War II agriculture found itself in very much the same situation as in the prewar period. In 1948 the government increased parity payments for the basic commodities; i.e., corn, wheat, peanuts, rice, cotton, and tobacco to 96 percent. The parity formula was changed to account for the increase in productivity which had occurred since the 1910-14 base period. The new formula was to reflect ". . .the pattern of relationships among parity prices dependent upon the pattern of relationships of the market prices of such commodities during the most recent moving 10-year period (Rasmussen, Baker, and Ward, 1976, p. 10).

The Korean War in 1952 induced the government to increase to 90 percent the parity payments for the basic commodities. Parity had been put on a sliding scale in 1949. Continued increased production and stocks led to the Agricultural Trade Development and Assistance Act (better known as PL 480) in 1954. This act allowed for disposal of agricultural products in foreign markets.

So far, all efforts had failed to bring demand and supply in line. Another serious effort was made by creating a soil bank. Farmland was to be taken out of production for payments and put into acreage reserves and a conservation reserve. The acreage reserve was established to reduce the amount of land allocated to allotment crops while the conservation reserve was to reduce the cultivated land in general for a longer time period. This latter reserve, however, soon ran into opposition. Whole farms were deposited into the reserve, disrupting rural communities in terms of employment and income.

Agricultural controls were maintained throughout the 1950s and 1960s with emphasis on wheat, corn, and cotton.

In 1970 under the Nixon administration, acreage allotments and marketing quotas were discontinued for wheat, upland cotton, and feed grains. To qualify for price support, ". . .the farmer was required to keep a specific percentage of cropland out of production, with this acreage set aside to be put to conserving practices" (Rasmussen, Baker, and Ward, 1976). The farmer could then grow whatever he desired on his remaining land except for crops under quota programs. Also, the administration set a maximum program payment ceiling of $55,000 for any one crop.

Finally, the Agricultural and Consumer Protection Act of 1973 rounds out the compensation policies. The Secretary of Agriculture was emphatic about "getting government out of agriculture" and proclaimed that the present act was ". . .an historic turning point in the philosophy of farm programs in the United States" (Rasmussen, et al., 1976 , p. 19).

This act developed a new concept of target prices. Target prices were only in effect if market prices fell below target prices. The target prices for 1974 and 1975 were set at 38 cents a pound for cotton, $2.50 per bushel for wheat, and $1.38 per bushel for corn. The total amount of payments to any person under the wheat, feed grains, and upland cotton programs was limited to $20,000.

Because of the current situation in world agriculture, the present farm programs seem very adequate. This should, however, not blind one to the obvious faults of some of the previous programs. It was obvious throughout many of the programs that as the total quantity of land and labor required to produce a given level of output diminished, the demand for total services from rural communities also declined. The forced exodus led to a rapid and unplanned rural-urban migration, the result of which is still obvious to date; for even though rural inhabitants were forced to leave, no alternative was available to them in either the rural or urban areas. Rural industrialization was considered an alternative but had only limited success. Thus, farm programs have carried some nonpositive benefits for the rural communities and unskilled workers. Such nonpositive benefits accrued not only to those affected but also to society as a whole for not realizing the additional gains to be had from the freed labor force.

More recently the public policy debate between the government and farm leaders has centered on such issues as fertilizer and pesticide use controls as well as other restrictions that indirectly or directly affect the environment. Public policy is a very important tool in charting the course of the nation's agriculture. Good agricultural policy means that the government must be able to administer the proper ingredients to agriculture to satisfy both domestic and foreign demand. However, at the same time, agriculture must be able to rely on a strong market institution that guarantees the farmer a market return on his investment, if once again agriculture suffers from overproduction.

Demand for Agricultural Products

Another factor contributing to the nature of the farming industry is the characteristic of demand for agricultural products. The main determinants of demand are: (1) the price of the good, (2) prices of substitute and complementary goods, (3) personal disposable income, (4) tastes and preferences, and (5) the size of the population (Henderson and Quandt, 1971). Hathaway contributes to this list as he discusses potential sources of shifts in the aggregate demand for farm products: (1) changes in population, (2) changes in tastes and preferences, (3) the development of new uses and(or) substitutes for farm products, (4) shifts in export demand, and (5) changes in the level of income and employment (Hathaway, 1963, p. 132).

Because food is one of man's basic necessities the demand for food is directly related to the growth of population. In early stages of economic development the demand for food increases as the population increases. Too, the demand for all commodities tends to be rather elastic because income is low relative to prices of those commodities. Of course, the influence of income and price depends upon the per capita income level. At this stage, however, per capita income levels are so low that the bulk of the food and other necessities is produced or prepared at home. As incomes increase or prices fall, food demand increases greatly; i.e., the income and price elasticities of demand for food are considered to be relatively high compared to the same elasticities in the more developed countries. For as incomes increase under economic development, per capita consumption ultimately reaches a level where no more food can be consumed. The consumer's demand for food will become less elastic as he marginally spends less on food as his income increases. As the country moves through the various stages of development, the consumption pattern is rearranged. In general, one observes a decrease in direct consumption of grain increases through a greater demand for livestock products.

Also, the quality of the food basket changes--more fruits, better cuts of meat, prepared foods, etc.

Most commodities are more elastic than those of food. This fact is, of course, related to the nature of the product. For example, in the United States food outlays make up only 17 percent of the per capita disposable income. The American consumer has little problem filling his stomach and thus, has turned his purchasing power elsewhere. It is because of this inelastic demand, coupled with an increase in production of food which has been faster than the increase in demand for food, that the income share of agriculture has declined relative to the rest of the economy.

The demand for food is almost as inelastic with respect to price as it is to income. Price elasticities are estimated to be as low as -.25 for some commodities.[19] This means that price must fall as much as 40 percent to increase the quantity of food demanded by 10 percent.

The responsiveness of income and price very soon diminishes as incomes rise and prices fall relatively and(or) absolutely. This phenomenon will be with agriculture as long as it produces more food (through efficient production and rapid adoption of new technology) than the consumer is willing to purchase. Thus, to clear the market, farmers must decrease price more than quantity increases, resulting in a lower income.

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[19] The price elasticity of demand is defined to be the percentage change in quantity demanded as the price of the commodity changes by 1 percent; i.e.,

$$\eta = \frac{p \cdot dq}{q \cdot dp} .$$

Per capita food consumption

Per capita demand for food, as previously pointed out, is subject to continuous changes. As the consumer's environment is altered because of changes in the level of income or prices or new external stimuli, consumption patterns change and adapt. Also, new developments in food processing industries may lead to new products or substitutes; e.g., margarine, and thus, change the per capita consumption of farm products. In the aggregate, the importance of changes in consumption, is the effect it has on agricultural production, resource use, and allocation of resources among the various region.

Tables 3.5 and 3.6 depict the changes in per capita consumption levels as changes in income and prices occur over time. The index shows that per capita consumption of animal products has increased with the exception of eggs and dairy products. Consumption of all animal products increased 32 percent. Poultry increased by 194 percent. Egg consumption diminished slightly from the 1939 level, while dairy products consumption decreased by 9 percent. The consumption of animal products has been subject to fluctuations brought about by: (1) price gyrations for these products which are a direct result of the grain price variations, and (2) the cholesterol "scare," which at least temporarily influenced buyers' attitudes with respect to animal products. Too, the influence of rising prices and declines in real income during the recent recessionary period can also be discerned. The 1974 consumption levels are down from those of 1972.

Table 3.5. Indices of domestic per capita consumption of animal products, 1939-1974[a], 1967 = 100

Year	All Animal Products	Meat	Poultry	Eggs	Dairy Products
1939	84.6	79.3	36.8	92.6	107.2
1940	87.4	84.5	37.9	94.3	107.2
1941	88.7	85.7	41.0	92.1	108.3
1942	89.8	84.8	45.9	93.1	114.4
1943	92.4	88.7	57.0	101.8	109.3
1944	94.5	93.8	51.0	104.0	111.3
1945	95.5	88.3	56.0	117.7	115.0
1946	97.6	92.2	51.6	111.1	120.3
1947	96.1	92.6	47.1	114.3	115.7
1948	92.2	86.6	46.2	116.7	110.2
1949	92.3	86.0	49.5	115.7	110.2
1950	93.8	86.0	53.6	118.5	110.3
1951	92.0	81.9	56.7	120.0	108.6
1952	94.2	86.7	58.3	120.0	108.6
1953	96.1	92.4	58.1	116.7	107.5
1954	96.3	91.7	61.3	115.7	108.5
1955	97.7	95.9	57.6	114.3	109.8
1956	99.5	97.7	64.6	113.7	110.2
1957	96.6	92.5	68.7	111.9	108.5
1958	94.6	87.8	74.2	109.5	107.5
1959	96.9	91.9	76.8	109.0	107.2
1960	95.7	92.3	74.5	103.6	105.7
1961	95.8	91.7	82.0	101.4	104.3
1962	96.2	92.7	80.7	101.0	104.8
1963	97.3	95.7	82.0	98.2	104.1
1964	98.8	98.5	83.8	98.5	104.1
1965	96.9	93.9	89.2	97.0	103.4
1966	98.1	96.1	95.7	97.0	102.0
1967	100.0	100.0	100.0	100.0	100.0
1968	101.5	102.8	98.9	99.0	101.0
1969	101.2	102.2	103.3	98.0	100.1
1970	102.5	104.2	107.8	98.5	99.2
1971	103.8	107.2	108.6	97.1	99.2
1972	103.6	105.3	113.2	94.9	99.9
1973	99.0	97.9	107.1	90.7	99.3
1974	101.6	104.7	108.1	88.6	97.7

[a]SOURCE: U.S. Department of Agriculture, 1972; 1975a; 1976g.

Table 3.6. Indices of domestic per capita consumption of crop products, 1939-1974[a]

Year	All Crop Products	Vegetable Fats and Oils	Fruits	Vegetables	Potatoes and Sweet Potatoes	Flour and Cereal Products
1939	96.0	53.9	110.9	104.0	95.2	122.0
1940	96.4	50.6	108.8	105.1	91.8	123.7
1941	99.1	56.9	110.7	105.6	97.0	124.5
1942	94.9	52.4	97.6	110.3	98.6	125.5
1943	94.4	53.0	86.7	112.0	99.3	139.0
1944	98.6	52.1	98.4	117.0	104.9	127.2
1945	99.5	51.1	104.0	123.6	93.5	134.4
1946	102.0	54.4	114.9	119.3	93.2	132.1
1947	99.3	55.2	112.1	109.3	91.6	118.5
1948	97.3	59.2	107.7	106.2	75.9	117.0
1949	97.1	61.6	107.3	102.7	79.0	116.5
1950	98.1	67.4	103.0	102.4	76.2	115.4
1951	96.5	59.8	105.3	101.8	76.3	118.2
1952	97.7	69.0	107.9	101.4	68.7	116.1
1953	97.2	70.5	105.6	100.2	72.7	113.5
1954	96.6	77.2	104.3	98.6	72.5	111.2
1955	96.1	75.6	103.8	100.2	73.6	105.3
1956	96.3	73.3	105.1	100.0	70.2	103.8
1957	95.3	73.1	105.5	99.4	71.0	102.2
1958	95.1	75.9	100.9	98.2	70.6	103.8
1959	96.7	79.4	104.1	97.6	76.1	103.0
1960	97.1	80.7	102.8	98.9	79.0	102.6
1961	96.4	78.5	99.3	97.7	80.2	101.9
1962	96.5	81.4	98.7	97.2	82.1	101.0
1963	95.9	85.1	90.0	97.0	85.9	100.1
1964	96.4	90.3	90.9	96.7	87.9	100.7
1965	97.6	91.9	94.7	97.8	92.4	100.9
1966	98.6	101.8	95.2	97.5	100.4	99.4
1967	100.0	100.0	100.0	100.0	100.0	100.0
1968	101.0	104.0	97.3	100.4	104.0	100.7
1969	102.0	110.4	100.2	100.7	110.4	101.1
1970	103.1	116.3	102.4	101.2	112.0	98.1
1971	102.8	113.2	102.2	100.8	112.6	98.9
1972	103.8	119.8	99.7	101.7	113.4	97.7
1973	105.3	126.9	101.9	104.5	111.9	98.0
1974	103.3	120.6	102.6	103.3	112.2	96.2

[a]SOURCE: U.S. Department of Agriculture, 1972; 1975a; 1976g.

Table 3.6 presents indices of crop products. Except for vegetable fats and oils which increased 122 percent during the 1939-1974 period, per capita consumption of crop products has not changed greatly. All crop products consumption increased 8 percent; fruits decreased 7 percent; vegetables remained nearly constant; and potatoes and sweet potatoes increased 18 percent. Finally, direct per capita consumption of flour and cereal products decreased 21 percent from the prewar level.

As mentioned at the beginning of this chapter, one of the factors that influence consumption was elasticity of income. Commodities that have a greater income elasticity increase more compared to those with small elasticities as per capita income increases, e.g., meat consumption versus flour and cereal products.

The per capita demand for cotton fluctuated between 25 and 42 pounds during the 1940s and the early 1950s. At that time, with developments of substitute products such as the synthetic fibers, demand for cotton began a steady decline. In 1974 the preliminary estimate of cotton consumption was 15.6 pounds, down from 27.7 pounds in 1939. Cotton consumption reached peak levels during World War II and the Korean War. The current outlook for cotton is that per capita consumption levels will stabilize around the current quantity of 16-18 pounds (Table 3.7).

Table 3.5. Per capita consumption of cotton lint, 1939-1974[a]

Year	Per Capita Consumption Cotton Lint (pounds)	Year	Per Capita Consumption Cotton Lint (pounds)	Year	Per Capita Consumption Cotton Lint (pounds)
1939	27.7	1950	30.9	1960	23.2
1940	30.0	1951	31.5	1961	22.2
1941	38.9	1952	28.5	1962	22.5
1942	41.8	1953	27.9	1963	21.4
1943	38.6	1954	25.4	1964	22.1
1944	34.6	1955	26.5	1965	23.1
1945	32.3	1956	25.9	1966	23.6
1946	34.0	1957	23.7	1967	22.3
1947	32.4	1958	22.2	1968	20.7
1948	30.4	1959	24.5	1969	19.4
1949	25.7			1970	18.6
				1971	19.1
				1972	18.5
				1973	17.4
				1974	15.6[b]

[a]SOURCE: U.S. Department of Agriculture, 1975a.

[b]Preliminary.

Export demands

The demand for exports of U.S. agricultural products has increased greatly over the past three years (1973-75), and prospects are that export demand will remain high in the immediate future. Exports are part of an integrated whole that links economic entities and thereby creates the interdependence that is so typical of a free world market system.

It also is because of such a system that the U.S. export market is often subject to large fluctuations from one year to another. The causes of fluctuations in exports have been explained in Chapter I. Weather--the variable causing most of the variation, is beyond control of man. It is therefore reasonable to assume that in the aggregate, exports will continue to fluctuate.

More gradual and smooth changes are caused by changes in taste, income, and population in the importing countries. Continued improvement of the standard of living elsewhere will eventually be expressed with greater demand for foreign products in those countries.

The United States, Argentina, France, Australia, and Canada account for almost all of the world's wheat and feed grain exports. Because the United States holds the largest share of the food and feed grain markets, it feels the immediate impacts of crop shortfalls elsewhere. Therefore, exports account for a large part of the fluctuation in farm income.

The foreign demand instability is caused primarily by foreign supply shortfalls and changes in taste and income (Hathaway, 1963). A host of other causes can be mentioned, such as realignment of currencies, crop shortfalls of related or substitute products, import and export restrictions, or other domestic policies. The above-mentioned relationships are reflected in Table 3.8. Total farm income and the value of commodities exported in the years 1970-75 show the relation between exports and farm income.

Table 3.8. Realized net U.S. farm income and value of exports of wheat, feed grains, and soybeans, 1970-75[a]

Year	Farm Income	Total Value of Exports	Wheat and Wheat Product	Feed Grains and Feed Grain Products	Soybeans and Soybean Products
	(billion dollars)			(thousand metric tons)	
1970	14.0	4.001	1.136	1.093	1.772
1971	13.0	4.094	1.112	.999	1.983
1972	17.2	5.146	1.479	1.548	2.119
1973	29.5	11.658	4.200	3.577	3.881
1974	27.7	14.365	4.634	4.698	5.003
1975[b]	23.7	14.430	5.353	5.283	3.794

[a] SOURCE: U.S. Department of Agriculture, 1976j.

[b] Preliminary.

How export quantities have developed over time can be seen in Table 3.9. Total agricultural exports have increased more than six times during the 1939-75 period. Since 1946 agricultural exports have steadily increased.

Cotton and cotton linters are probably the least predictable export commodities. During the early 1940s, cotton exports were low. An increase in demand occurred during the late 1940s and early 1950s. Another period of strong foreign demand occurred around the 1960s. Only recently (1974-75) has this strong foreign demand picked up again.

Grains and feeds and vegetable oils and oil seeds both have risen substantially. Recent world demand for both commodities has increased over the previous peak levels (which occurred during the mid-1960s coinciding with an alleged "food scarcity").

Table 3.9. Indices of the quantities of American agricultural products exported from 1939-1974

Year	Total Agricultural Exports	Animal and Animal Products	Cotton and Linters	Grains and Feeds	Vegetable Oils and Oilseeds
1939	26	18	92	13	1
1940	29	14	164	7	4
1941	12	18	32	6	2
1942	22	116	29	5	2
1943	25	151	32	4	5
1944	31	184	32	5	7
1945	30	136	42	7	6
1946	45	137	92	23	3
1947	46	87	99	32	4
1948	41	73	51	36	5
1949	52	66	119	41	14
1950	48	55	145	30	16
1951	48	65	108	37	18
1952	54	56	142	42	18
1953	40	48	76	32	14
1954	42	68	94	25	23
1955	48	94	92	28	32
1956	56	116	56	41	43
1957	77	109	185	54	47
1958	65	91	143	45	46
1959	62	83	79	52	51
1960	79	96	166	60	69
1961	84	98	176	69	65
1962	85	103	119	79	64
1963	84	104	91	79	78
1964	100	140	128	94	82
1965	98	130	113	92	99
1966	107	108	78	117	102
1967	104	101	115	103	95
1968	101	96	101	104	99
1969	92	110	69	85	106
1970	106	101	75	97	148
1971	115	117	98	106	158
1972	115	134	89	103	159
1973	153	123	126	167	182
1974	165	127	152	179	186

CHAPTER IV. METHODS AND COMPUTATION

This chapter will acquaint the reader with the alternatives analyzed and the method of computation used in this study.

The estimation procedure can be divided into two parts:

1) the estimation of domestic and foreign demands for the commodities internal to the model and
2) the allocation of domestic production and resources using a comparative advantage production model.

The domestic and foreign demands and production are estimated in a number of steps for the year 1980. The optimum allocation of resources and production is estimated using a national and interregional linear programming model that incorporates a comparative advantage production sector and a transportation sector.

The Setting

This study attempts to answer the question of how well agriculture can feed mankind. A limited number of changes in American and world agriculture is analyzed in relation to the amount of food to be produced. Such changes in agriculture are relevant only if world and national leaders are sincere in their efforts to bring about an abundant and a more equitable distribution of food among the world's inhabitants. Governments would need to provide incentives for and guarantees to the farmers with respect to future markets, and would need to create institutions that provide the farmer with favorable prices.

The study concentrates on U.S. agriculture relative to these changes. U.S. agriculture is treated as the residual supplier of food. Thus, as the rest of the world completely exhausts its supply (allowing for internal trade), U.S. agriculture is expected to supply the deficit to the limit of its capacity. Further, it is assumed that a world body will create the necessary means to distribute the food to the poor and malnourished people.

Alternative Futures

Six alternative situations are examined for the year 1980. These alternatives can be divided into two subsets, each of which relates to a separate issue. The first subset assumes that the United States will have "all out" production to help feed the world at any one of a number of required nutritional levels. The assumptions of the second subset include consideration of nutritional requirements as well as changes in "conventional" diet patterns. Specifically, consumers are requested to consume less meat or substitute plant protein for 25 percent of normal meat consumption. Too, changes in weather, which may adversely affect agricultural production in a number of regions elsewhere in the world are incorporated.

The six alternatives will be referred to as Alternatives A through F. The first, Alternative A, serves as a base situation for comparison with the other five. Under Alternative A domestic demands are first satisfied. Then, exports of wheat, feed grains, and soybeans are increased until the nation's land base, allocated to these crops, is fully utilized. However, the export proportion for the three commodities in Alternative A remains the same as the 1973-75 average export mix. The level of exports for the remaining alternatives will be estimated by foreign import demand based on 1980 income and population levels. Thus, if foreign import demands exceed U.S. export supply, an absolute deficit occurs. Cotton exports under all six alternatives are fixed at 4.2 million bales.

Alternatives B through F allow the export mix of the commodities to change to reflect a greater demand for wheat. The proportion of the wheat-feed grain ratio is set at 60:40. Soybean exports are estimated to be consistent with meat consumption in 1980.

Alternative B forces export demand to reflect the world's determination to satisfy every human being's daily caloric requirement. Demands do not reflect protein requirements because other research indicates that a well-balanced diet that contains sufficient calories will satisfy protein requirements (Youde and Carter, 1975).

Alternative C, the last alternative of the first subset, presents a more nearly equitable situation in food consumption. This alternative allows the rich nations to consume at levels dictated by economic variables such as per capita gross national product and income elasticities, but it also requires that the poorer nations be fed at recommended levels as under Alternative B. Whereas alternatives A and B give a good indication of the two extreme food requirements, alternative C is more feasible for policy-making purposes.

In the second subset the export mix of grain remains as under Alternative B. In this part of the analysis attention is focused on deviations from normal weather and shifts in consumption patterns.

Alternative D simulates an overall bad crop year. Research indicates that yields worldwide are positively correlated, which means that a bad harvest in country Y will probably lead to a less-than-favorable harvest in country Z (U.S. Department of Agriculture, 1974d, p. 73). The overall yield decrease is estimated to be 5 percent for all crops.

Alternatives E and F incorporate a shift in consumption. Alternative E assumes that developed countries reduce meat consumption by a modest 25 percent. In doing so the developed nations command less grains to be used for meat production and concurrently make available the released resources for the production of export crops. Implicit in this alternative lies the argument that the transformation of grain into meat may be rather inefficient. Later in this study the long-run implications of such an argument will be elaborated to some extent.

Finally, Alternative F simulates a bad harvest in the main exporting and producing nations, such as Canada, Argentina, Australia, France, Russia, and South Africa. Yields are assumed to drop a moderate 15 percent below trend. The food shortage resulting from such a situation is countered by a worldwide switch from animal to plant protein. The released feed grains are now used for human consumption.

This study ties together the results of one of the studies reviewed in Chapter II with a detailed linear programming model of American agriculture. The study can be divided into two major parts: the foreign sector and the domestic sector. Both sectors consist of smaller parts (production, demand, and transportation). First the foreign sector will be discussed.

Foreign Production and Consumption

In this section methods are developed to estimate domestic and export demand in different regions of the world.

Delineations of the model

One hundred and eighteen countries (as listed in Table 4.1) are included in this research. These countries represent over 98 percent of the world's population and are grouped into various regions, as indicated. The regional delineation is made on the basis of per capita income, geographical location, and political structure. The countries excluded are small nations for which data are not readily available or nonexistent.

Population projections

To project the increase in population across the world, the most recent population estimates and growth rates are used (Meyers, 1976). It is assumed that the growth rates will remain constant throughout the projection period. Too, it is assumed that numbers of both males and females will continue to grow at a constant rate.

Table 4.1. Delineation of world regions

Region Number	Region Name	Countries Included in the Region
1	Canada	Canada
2	Mexico	Mexico
3	Central and South America	Costa Rico, Cuba, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Panama, Trinidad-Tobago, Bolivia, Chile, Columbia, Equador, Paraguay, Peru, Venezuela, Guyana,
4	Brazil	Brazil
5	Southern America	Argentina, Uruguay
6	Africa	Algeria, Ethiopia, Libya, Morocco, Sudan, Tunesia, United Arab Republic, Somali Republic, Angola, Cameroun, Zaire, Ghana, Ivory Coast, Nigeria, Senegal, Sierra Leone, Upper Volta, Dahomey, Kenya, Malagasy Republic, Rhodesia, Liberia, Togo, Malawi, Zambia, Uganda, Tanzania, Mozambique, Rwanda and Burundi.
7	South Africa	Republic of South Africa
8	Northern Europe	France, Austria, Belgium-Luxemburg, Denmark, Finland, Ireland, Netherlands, Norway, Sweden, Switzerland, UK - Northern Ireland, West Germany, Iceland.
9	Southern Europe	Greece, Italy, Portugal, Spain, Yugoslavia
10	East Block Countries	East Germany, Poland, Hungary, Czechoslovakia, Rumania, Albania, Bulgaria,
11	U.S.S.R	U.S.S.R.
12	Middle East	Cyprus, Malta, Iran, Iraq, Israel, Jordan, Lebanon, Syria, Turkey, Saudi Arabia, Republic of Yemen, Afghanistan.
13	Central Asia	India, Sri Lanka, Pakistan and Bangladesh, Nepal.
14	Southeast Asia	Burma, Khmer Republic, Taiwan, Indonesia, Philippines, Hong Kong, North Korea, North Vietnam, South Korea, South Vietnam, Thailand, Outer Mongolia, Malaysia.

Table 4.1. Continued.

Region Number	Region Name	Countries Included in the Region
15	People's Republic of China	People's Republic of China
16	Japan	Japan
17	Oceania	Australia, New Zealand

Because nutritional requirements are of interest in this model, the population is divided into 17 groups by age and sex, each group having its own requirements. In the few cases where sex-specific data are unavailable, a 50-50 proportion is used. After age 11 each sex is subdivided into seven age classes, while the age group of 0 to 10 is a combination of males and females (Table 4.2).

The division of classes is based on the availability of data for the countries in question as well as the guidelines established by the FAO/WHO Ad Hoc Committee Report (Food and Agriculture Organization, 1973, p. 80; United Nations, 1974b). Because the two reference sources used do not conform with regard to age classes, a new set of classes is developed. The assumption is made that the distribution in each age group is uniform.

Thus, the number of people for an individual sex-age class is projected to 1980 as follows:

$$P^{80}_{i,j,k} = P^{m}_{i,j,k}(1+r_k)^{80-m} \qquad (4.1)$$

Table 4.2. Calculations of per capita energy requirements[a]

Age Group (year)	Requirements by age and sex in calories in (KCAL)[b]	
(1) < 1	1090	
(2) 1-4	1478	
(3) 5-9	2046	
Male: adolescent, adult		
(4) 10-14	2724	
(5) 15-19	1.02	* NR[c]
(6) 20-39	1.00	
(7) 40-49	.95	
(8) 50-59	.90	
(9) 60-69	.80	
(10) 70+	.70	
Female: adolescent, adult		
(11) 10-14	2540	
(12) 15-19	1.05	* NR[d]
(13) 20-39	1.00	
(14) 40-49	.95	
(15) 50-59	.90	
(16) 60-69	.80	
(17) 70+	.70	

[a]SOURCE: Food and Agriculture Organization, 1973.

[b]It is assumed that young children (age groups 1, 2, and 3) have identical requirements across all regions.

[c]Requirements for reference adult males (as in Table 20).

[d]Requirements for reference adult women (as in Table 20).

where

$P^{80}_{i,j,k}$ = population of sex i in the jth class in country k in 1980, i = 1,2; j = 1,...,17; k = 1,...,118;

$P^{m}_{i,j,k}$ = population of sex i in jth class in country k in year m;[20] and

r_k = population growth rate of country k.

Projected population by country is obtained by summing over age and sex classes, i.e.:

$$\sum_j \sum_i P^{80}_{i,j,k} = \sum_j \sum_i P^{m}_{i,j,k}(1+r_k)^{80-m} \qquad (4.2)$$

Summing over the k countries yields total population:[21]

$$\sum_k \sum_j \sum_i P^{80}_{i,j,k} = \sum_k \sum_j \sum_i P^{m}_{i,j,k}(1+r_k)^{80-m} \qquad (4.3)$$

The country populations are finally aggregated into the 17 regions as outlined above.

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[20] The value of m denotes the year of the most recent available data for the particular country.

[21] Life expectancy is assumed to be constant for the period.

Nutritional requirements

The population estimates obtained are used as inputs into a set of nutritional requirement equations for three climatological regions in the world. Lack of data on an individual-country basis forces nutritional estimates to be made using geographic and demographic regions. These regions are considered to be representative for all populations in those regions (National Academy of Science, 1964, p. 58).[22]

Each individual is different in that he has different needs and wants. No two humans are the same physically and will, thus, require different amounts of food; i.e., because of different metabolisms the intake of calories and proteins will differ. Such detail is usually not possible for large-scale studies. Unfortunately, nutritional requirements for individual countries are not widely available. Therefore, comparative dietary standards for adults in selected countries were taken as a base for the nutrition regions mentioned above (Table 4.3). Using the above information of reference adults for the regions, the FAO/WHO report findings were used to develop a set of nutritional lower bounds for the 17 demographic classes (Table 4.4).

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[22]The three regions are the temperate zone, the subtropical zone, and the tropical zone. The three zones have a different set of nutritional requirements because of demographic and geographic differences as well as different population characteristics.

Nutritional recommendations are very difficult to make. Because of the ad infinitum string of variations within a country or among countries, any recommendation is by necessity a rough estimate of the requirements of a whole population. The FAO/WHO Committee had considerable problems in defining what exactly constitutes a nutritional and healthy diet. In fact, a considerable controversy has developed among nutritionists about such recommendations. It seems, in retrospect, that the protein recommendations are too low.[23] The report points out that:

> . . . protein is used inefficiently if energy intake is grossly inadequate. The extent to which inadequacy of energy intake affects protein utilization and the extent to which additional intakes of protein can be utilized to meet protein requirements in the presence of caloric inadequacy needs much further investigation, particularly in the borderline situation where energy intake is inadequate but not grossly inadequate (Food and Agriculture Organization, 1973, p. 98).

Table 4.3. Basic daily recommended allowances for selected regions in the world[a]

Zone	Sex	Weight Kg	Activity	Calories	Protein
	M	65	Moderate	3,000	87
Temperature	F	56	Moderate	2,500	73
	M	56	Moderate	3,000	70
Subtropical	F	48.5	Moderate	2,400	60
	M	55	Moderate	2,800	55
Tropical	F	45	Moderate	2,300	45

[a]SOURCE: National Academy of Science, 1964.

[23]Dr. N. S. Scrimshaw, member of the Committee, referred to the controversy as the energy-protein conflict. He recommends a 10-percent increase in the protein recommendations (personal communication with Dr. N. S. Scrimshaw).

Table 4.4. Daily calorie requirements, adjusted for body weight and climate, by sex and region

Region	MALES Age Groups (years)									
	<1	1-4	5-9	10-14	15-19	20-39	40-49	50-59	60-69	≤70
Temperate	1,090	1,478	2,046	2,724	3,030	3,000	2,850	2,700	2,400	2,100
Sub-Tropical	1,090	1,478	2,046	2,724	3,030	3,000	2,850	2,700	2,400	2,100
Tropical	1,090	1,478	2,046	2,646	2,828	2,800	2,720	2,520	2,240	1,960
Region	**FEMALES Age Groups (years)**									
	<1	1-4	5-9	10-14	15-19	20-39	40-49	50-59	60-69	≤70
Temperature	1,090	1,478	2,046	2,540	2,665	2,500	2,375	2,250	2,000	1,750
Sub-Tropical	1,090	1,478	2,046	2,495	2,558	2,400	2,280	2,160	1,920	1,680
Tropical	1,090	1,478	2,046	2,450	2,452	2,300	2,185	2,070	1,840	1,610

The recommended energy requirements and safe level of protein intake may be used for evaluation of the gross availability of energy and protein supplies of nations, for planning food supplies and diets, for planning and evaluating food programs, etc. (Food and Agriculture Organization, 1973, p. 11).

It may be helpful at this point to give the definitions of energy requirement and safe level of protein intake.

Definition 1: "The energy requirement of persons is the energy intake that is considered adequate to meet the energy needs of the average healthy person in a specified category (Food and Agriculture Organization, 1973, p. 10)."

Definition 2: The safe level of protein intake is the amount of protein necessary to meet the physiological needs and maintain the health of nearly all persons in a specified group (Food and Agriculture Organization, 1973, p. 10)."

The definitions above are based on an average healthy person. Some persons need more than others, but on the average these differences will cancel out. However, the sick, underfed, and malnourished people need a different diet, which is not accounted for here. The nutritional requirements for any given class were calculated as follows.

$$NR_{i,j,k} = P^{80}_{i,j,k}K_{i,j,m} \tag{4.4}$$

where

$NR_{i,j,k}$ = total amount of energy (kcal) needed for sex i of the jth age class in country k;

$P^{80}_{i,j,k}$ = as in equation 4.1; and

$K_{i,j,m}$ = amount of energy needed per person of sex i of the jth age class in region m (m = 1,2,3).

Thus, total amount of energy needed across sex, age, and country is:

$$\sum_k \sum_j \sum_i NR_{i,j,k} = \sum_k \sum_j \sum_i P^{80}_{i,j,k} \cdot K_{i,j,m} \qquad (4.5)$$

As mentioned elsewhere, the main emphasis is on energy because it is felt that a well-balanced diet with adequate calories will allow sufficient proteins to be consumed. Consumption above is expressed in kilocalories (kcal) so that a common base is established for calculation purposes. The same procedure will be followed for production so that eventually an account can be given as to the status of any nation's food supply.

Production projections

Every country in this study has at least some domestic production of one or more crops. For purposes of estimation the domestically-grown crops are divided into wheat, feed grains, and soybeans on the one hand, and all other crops on the other. Production of the latter group will be discussed first.

Analysis of past trends

The production projections of the foreign sector are based on a subjective trend-based approach. The study's results are appraised in light of the basic assumptions, which include constant real producer prices, unchanged government policies, and continuation of present technological developments (Food and Agriculture Organization, 1971, p. LV). A systematic study of past production trends for the period 1955-1969 is carried out for over 30 agricultural commodities including the analysis of past trends of area, yields, and livestock output for all important producing countries. A number of functions are fitted, taking "time" as the only explanatory variable. In the majority of cases the linear and weighted linear regression equations are used. Only in a small number of cases the two other functions are fitted for the sole purpose of establishing a projection base. The orthogonal polynominal was not used to project but served merely as a guide.

The methods used in projecting production differ by crop or commodity. A detailed account for each major commodity group can be found in the FAO study (Food and Agriculture Organization, 1971, pp. LVI-LX).

Crop production

The estimates for all commodities, except wheat, feed grains, and soybeans, are directly derived from an FAO study (Food and Agriculture Organization, 1971). The general approach in the FAO study was to

". . . make trend-oriented projections independently for production and demand, assuming constant prices and with no major changes in policies prevailing at present, but allowing for technological developments" (Food and Agriculture Organization, 1971). The major limitation, which goes along with a model of commodity-by-commodity projections such as this study is, of course, the failure to take into account the interrelationships among commodities and the implications of these projections for purposes of agricultural resource use.

The FAO projections of production consisted of the following commodities or commodity groups:

a) food and feed (grains, rice, dairy products, meat, fish, fats and oils, sugar, citrus fruit, bananas, oil cakes, and fish meal);
b) beverages (coffee, cocoa, tea, wine) and tobacco;
c) agricultural raw material (cotton, wool, jute, kenaf and allied fibers, hard fibers, hides and skins, rubber); and
d) forestry products (wood, pulp, and paper).

For our purposes only the commodities under group (a) are of direct interest and though not included under (a), other products such as starchy roots, pulses, vegetables, and fruit have been included in the study for nutritional considerations. All the commodities are further subdivided into subcategories (Food and Agriculture Organization, 1971, pp. XXIX-XXXIII).

The projections of wheat, feed grains, and soybeans are based on ordinary least squares estimates. Only in a few instances were corrections necessary (Mitchell, 1976). The data for these crops are obtained from U.S. Department of Agriculture (1974b).

Demand projections

The quantity of food demanded depends on a number of variables, such as population, per capita income, and relevant prices. In this study, demand was estimated at constant 1970 retail prices.

The starting point of the demand projections is the compilation for each of the 118 countries of standardized food balance sheets for the period 1964-66, showing per capita consumption of all items in the diet in terms of kilograms (kg) per year and of calories, proteins, and fats per day. From such balance sheets indices of increases in per capita and total demand in terms of quantities and nutrients were projected for the year 1980.

The approach assumes that population and income are the major shifters of demand. In the demand model income is included through the application of preselected values of income elasticities (for each commodity) and appropriate demand functions, reflecting the way in which demand changes with increased incomes. To capture other changes in the model not accounted for, a trend factor is included. This parameter is introduced to take into account such changes as rural-urban migration, changes in preferences, income distribution, marketing, etc.

Starting from the net food consumption as indicated on the food balance sheets (1964-1966), 49 commodities were projected to 1980. For space limitations, only one set of tables for one country will be presented in Appendix A. It is from these tables that nutritional information is derived.

All foods produced are converted into calories, making certain assumptions about seeding rates, extraction rates, grain for feed, industrial uses, and waste. At the bottom of Table A-1, the calories, protein, and fats have been entered to provide the final estimate of per capita consumption.

The Domestic Model

The domestic model: 1) estimates the demand for the endogenous crops and 2) derives the solutions to provide the basis for the different alternatives. The programming model is presented in detail in Appendix B. It is felt, however, that by providing a skeleton framework at this point, the results presented in the next chapter should take on greater meaning.

The programming model

A linear programming model is used to estimate production, supply prices, and allocation of resources in the year 1980. The results of the model are then used for further analysis.

The model incorporates the wheat, feed grains, soybeans, corn and sorghum silage, and cotton sectors of U.S. agriculture. The model consists of an interregional comparative advantage production sector, a transportation submodel, and a set of resource restraints. The model also requires the fulfillment of consumer demands. Production costs, yields, and demands are estimated for the year 1980.

The programming model minimizes the cost of producing the crops endogenous to the model (wheat, feed grains, soybeans, corn and sorghum silage, and cotton) in 150 producing regions and of transporting them among 31 demand regions. The model simulates a production equilibrium in that it equates the supply price of each crop to the cost of producing that commodity in each producing area. Too, the model simulates a market equilibrium in that it equates the quantity produced with the quantity demanded of each crop in each demand region.

The demands are determined exogenously in the model and are specified for winter and spring wheat, feed grains, silage, and oilmeals in each of the 31 demand regions. The demand for cotton lint is determined at the national level. The demands for these commodities are encompassing total usage; i.e., they are a summation of domestic human consumption, livestock feed, other industrial uses, seed, exports (in raw and processed form), and waste.

Transportation activities are defined to allow commodities to be transported among demand regions in order to satisfy requirements. There are a possible 31 x 30 = 930 transport activities for each commodity. For the four crops this totals to 4 x 930 = 3,720 transportation activities. However, taking into account historical production patterns and movement of these commodities, the number of activities was reduced to 1,603 (202 for spring wheat, 467 for winter wheat, 458 for feed grain, and 476 for oilmeals). Transportation costs are based on rail rates between the various regional demand centers. No costs are involved for intraregional transportation; i.e., from a producing area to its regional demand center.[24]

[24]No transportation activities are involved for silage between demand regions.

The production activities for spring and winter wheat, feed grain, and oilmeals are expressed in feed units.[25] This allows the aggregation of corn, oats, barley, and sorghum into one commodity: feed grains. It also allows demand to be satisfied by either soy oilmeal or cottonseed oilmeal.

The programming model contains 307 equations and 2,214 real variables. Land serves as a resource constraint in each of the 150 producing areas. In addition, the demands for the commodities serve as constraints in the 31 demand regions plus the national demand for cotton lint. The real variables include crop production and transportation activities.

The solution of the model provides data concerned with the allocation of production and supply prices for the wheat, feed grains, silage, soybeans, and cotton commodities.

Expressing the model in its algebraic form, it can be observed how the above output data is generated. The model is based on cost minimization. Thus, the objective function is such that a set of activities must be found that fulfills the various constraints but at the same time minimizes production cost. Rewriting in algebraic form:

$$\min f(X) = C'X$$

$$\text{such that} \quad AX \geq b$$

$$X \geq 0$$

[25] A feed unit is the quantity of feed that is equivalent to the feeding value of a pound of corn (containing 78.6 percent TDN) (U.S. Department of Agriculture, 1974c).

where

X = a column vector of production and transportation activities;

C = a row vector of unit cost for the above activities;

b = a column vector of resource and demand restraints; and

A = a matrix of input-output coefficients.

The minimization model output yields information pertaining to the allocation of production. The dual to this problem solves the question of prices that must be paid for the resources used in the production process, and can be written as follows:

$$\max f(q) = b'q$$

$$\text{such that} \quad A'q \leq c$$

$$q \geq 0$$

where q is a column vector of land rents and supply prices for the products and c, b, and A are as defined above.

Because of the complexity of the agricultural sector represented in this model, and the difficulty to present such a complex system into a linear programming framework, a number of simplifying assumptions is made to allow formulation of the problem this study has set out to investigate. The following list presents basic assumptions necessary for proper formulation:

1. There are n unique spatially separated and interdependent producing regions, each containing many producers of at least one of the crop activities (wheat, corn, oats, barley, sorghum, soybeans, corn, and sorghum silage and cotton).

2. Constant returns to scale exist for each crop in each producing region.
3. Total productive capacity is bound by the availability of land allocated to the crops endogenous to the model.
4. Within each region land is homogenous and substitutable between crops subject to a) agronomic restraints and b) technological restraints as outlined in Appendix B.
5. The combination of the feed grains into feed units is of the same proportion in each producing region.
6. There are m unique, spatially-separated and interdependent demand regions, containing demands for the feed grains, oil-meals, spring and winter wheat, and corn and sorghum silage.
7. The demand restraint for cotton is estimated at the national level.
8. Domestic and export demands for the crop commodities are estimated exogenously of the programming model.
9. Transportation costs among demand regions are estimated on the basis of railway freight rates.
10. The transportation sector has sufficient capacity to transport any quantity of any commodity called for in the model.
11. No depletion or building up of stock or reserves are allowed in the model; i.e., the model assumes a constant level of reserves through time.

12. Minimization of costs production is assumed to adequately reflect the attitude of the farmer and American society.

Delineations of the model

The model is regionalized in a number of ways. The smallest entity is the producing area. The model contains 150 producing areas within the contiguous 48 states of the United States (Figure 4.1), for which crop-producing activities have been defined. The producing areas are defined to be homogenous with respect to productivity, which includes such factors as soil type, topography, climatological data, yields, and production costs. Each of the producing areas is wholly contained within a demand region. This feature facilitates easy computation of production activities within the demand regions and transportation activities between regions. Only 2 percent of the 1969 production of the commodities included in the model is not accounted for. The areas that bring forth this production are called the White Areas (U.S. Department of Commerce, 1971). In this analysis production of the White Areas is held constant at the 1969 level, and the demands as specified in this model are adjusted for such production.

The 31 demand regions are developed as separate areas for winter wheat, spring wheat, feed grains, and oilmeals (Figure 4.2). The areas are delineated such that they follow state boundaries, thereby facilitating computations concerning individual or groups of states. Only the demand for cotton lint is not regionalized; it is specified at the national level.

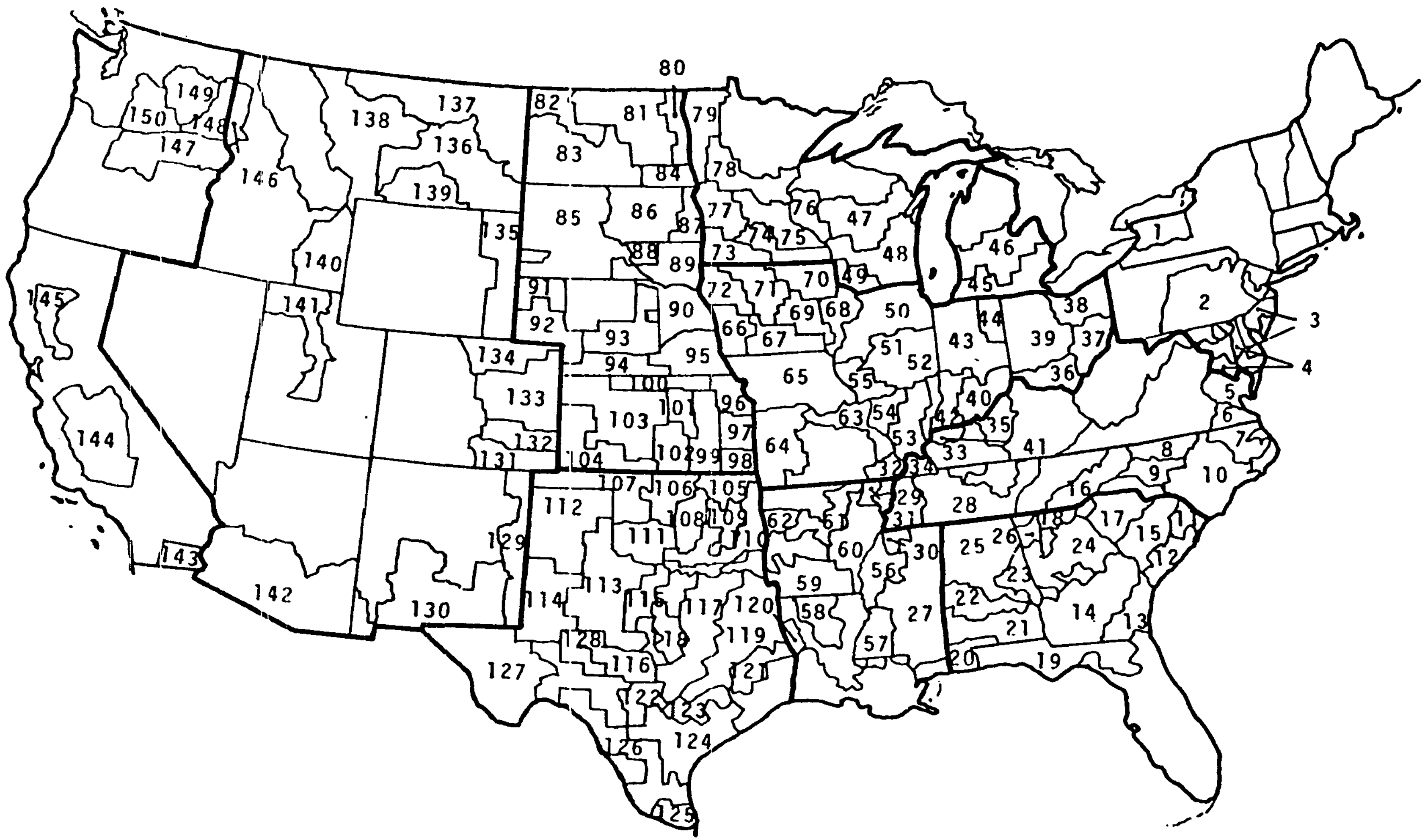

Figure 4.1. Location of producing areas and farm production regions used in this study

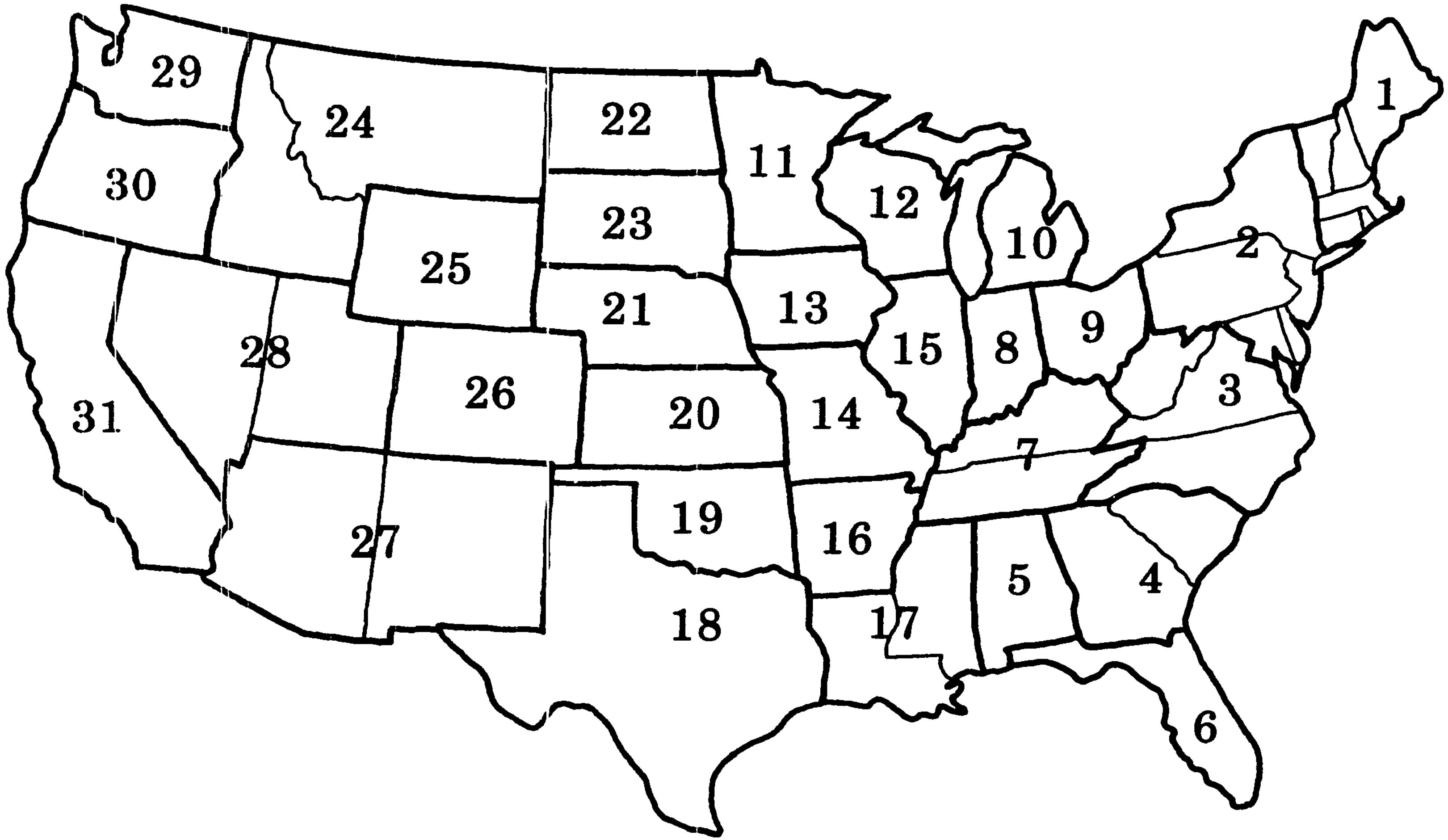

Figure 4.2. Location of consuming regions used in this study

The last regional concept used in this study is the farm production region. The 10 farm production regions as outlined in Figure 4.1 include all of the 150 producing areas and follow state boundaries; i.e., each producing area and demand region is entirely contained in one farm production region. The composition of the farm production regions is conforming to USDA regions. Many of the results of this study are reported at the farm production region level.

Livestock consumption

Although the specified goal of this study is estimation of export demands, estimates of domestic consumption also are needed. Indeed, domestic demands must be fulfilled before any commodity can be made available for exports. The domestic consumption of livestock feed is such an important part of total domestic demand for feed grains and soybeans, and domestic consumption of livestock products plays such an important role in this analysis that the demand estimates are presented in some detail in Appendix C.

CHAPTER V. RESULTS AND INTERPRETATIONS OF THE MODEL ALTERNATIVES

Each model solution simulates production possibilities and provides approximations of the agricultural production pattern at a specific point in the future. Each alternative solution estimates the agricultural production and resource use pattern in 1980, subject to the conditions upon which the model is built. The results are reported at the farm production level and the national level.

National Production, Acreage, and Yield

Estimates of total production, acreage, and yield are derived from the solution of the programming problem (Table 5.1) for each model alternative. Total national acreage is forced to remain around 250 million acres for all model alternatives, even though the model's land base is more than 251 million acres. To allow the model to use all available land results in unstable supply prices and relatively high computing costs. Consequently, total acreage is kept below the maximum so that the effects on export and production potential are more definitive. Based on the comparative advantage principle, spatial allocation of crop production varies between the alternatives because of different domestic demands and export mixes among the alternatives. The magnitude of output and exports can be seen in Figure 5.1.

Table 5.1. Estimated production, acreages, and yields for each of the model alternatives with 1973-75 values of comparison

	1973-75 Actual[a]	A	B	C	D	E	F
		Model Alternatives					
	Total production (millions)						
Wheat (bu.)	1,878.4	2,301.2	2,460.9	2,619.6	3,109.4	3,023.0	2,119.3
Feed grains (tons)	196.2	261.9	198.3	242.9	212.4	217.4	214.6
Soybeans (bu.)	1,427.8	1,415.1	1,270.4	1,453.9	1,506.5	1,496.0	1,564.6
Cotton (bales)	10.9	12.1	12.1	12.1	12.1	12.1	12.1
Silage (tons)	120.1	172.6	151.6	172.6	151.6	155.1	155.8
	Harvested acres (millions)						
Wheat	63.0	68.7	70.8	78.2	91.5	88.7	61.5
Feed grains	102.5	112.4	83.7	103.1	89.1	91.0	91.9
Soybeans	53.9	45.9	37.2	46.0	46.8	46.9	51.4
Cotton	11.2	10.0	10.2	10.1	10.1	10.1	10.1
Silage	10.5	13.3	11.8	13.2	11.7	12.0	12.0
Total	241.1	250.3	213.7	250.6	249.2	248.7	226.9
	Yields						
Wheat (bu.)	29.79	33.49	34.77	33.50	33.97	34.07	34.45
Feed grains (bu.)[b]	68.33	83.25	84.59	84.19	85.16	85.35	83.30
Soybeans (bu.)	26.48	30.83	34.14	31.60	32.19	31.89	32.18
Cotton (lbs.)	469.19	579.56	570.29	576.48	576.87	576.81	573.90
Silage (tons)	11.42	12.94	12.89	13.08	12.92	12.94	12.91

[a]SOURCE: U.S. Department of Agriculture, 1976e.

[b]Feed grain yields are reported on corn equivalent basis.

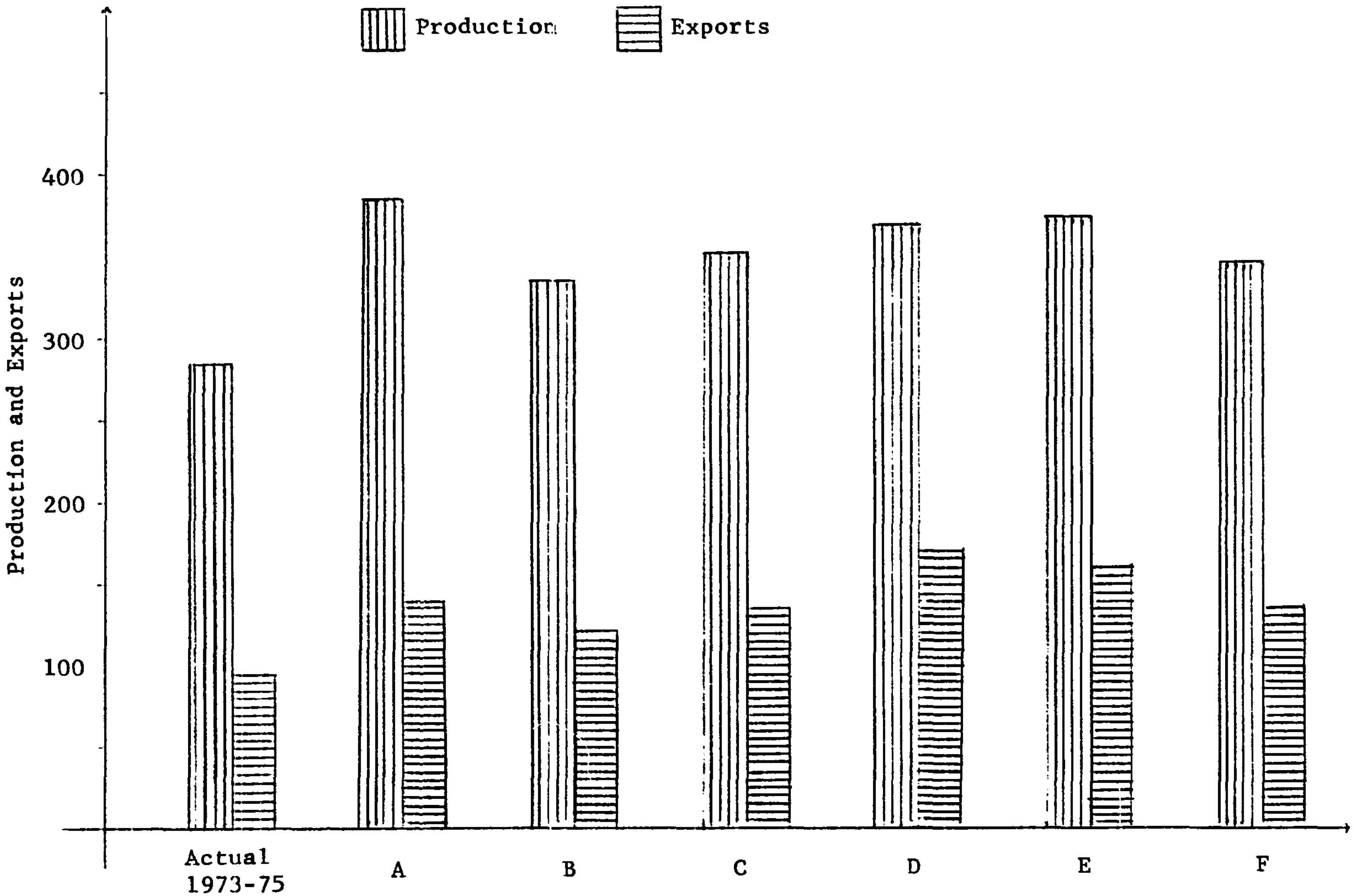

Figure 5.1. Estimated production and exports of wheat, feed grains, and soybeans for each model alternative (expressed in millions of tons of feed units)

Export potential of U.S. agriculture is estimated in terms of food and feed grains. Cotton exports are held constant among all alternatives. This approach facilitates the comparison between the different model alternatives with respect to the potential exports for wheat, feed grains, and soybeans.

Alternative A, 1973-75 export proportions

Alternative A, the base alternative, represents the maximum export capacity of the three export commodities (in 1973-75 average proportions). It is assumed that agricultural policy calls for "fence-row to fence-row" production--an effort to make available as much food as possible to the world at prevailing market prices. Exports are increased by 42 percent over the 1973-75 actual level. The total amount of land in production, 250.3 million acres, is almost 9.2 million acres more than the 1973-75 acreage. Yields of all commodities are considerably higher than the 1973-75 average yields. Wheat, feed grains, and soybeans increase 12.4 percent, 21.9 percent, and 16.4 percent, respectively. Cotton yield increases 23.5 percent. Silage yield is projected to increase 13.3 percent (Table 5.1).

The number of harvested acres increases by 9 million acres to 250.3 million acres relative to the 1973-75 actual acres harvested. Feed grains use most of the additional area (10 million acres). The relatively large increase in feed grains production and acreage is a result of domestic and export demand for feed grains for the livestock industry in the developed countries. Only a small part of the feed grains will be directly consumed by the people in the developing countries. Wheat commands an additional 5.7 million acres. Most of the additional acreage is used for production of additional domestic demand (because of increased population) and for export demand in the developing countries as well as the East-bloc countries, if present export trends persist. Soybean acreage declines 8 million acres from its 1973-75 average level. This is no surprise because the soybean export market has been very strong in recent years. Brazil is rapidly increasing its soybean acreage, producing as much as 20 to 25 percent of American production, and will continue to increase its share in the soybean export market. Because of the recent high prices, many soyoil substitutes are competing for the vegetable oil market. The most important competitor is palm oil. Cotton acreage declines slightly from the 1973-75 level even though total production increases. The additional production is brought about by the projected rise in yields (23.5 percent) by 1980.

Not too much should be made of the differences between the 1973-75 actual production statistics and those estimated under the various alternatives because the outcomes are only a reflection of the model. However, these differences do show the potential of U.S. agriculture (if present trends persist) and may give the reader a better feel for the magnitude of the numbers reported. The increased production under Alternative A compared to the 1973-75 average levels is because: a) land is drawn into production that was previously tied up in government conservation or set-aside programs; b) yields of the endogenous commodities are projected to increase as a result of improved technology by 1980; and c) all crops are spatially allocated among the 150 producing regions according to their comparative advantage in the production of each crop.

Alternative B, nutritional requirements

Alternative B assumes that world opinion has shifted toward creation of a more equalitarian society in terms of food distribution. This alternative requires nations to diminish consumption (if they currently consume more than the daily recommended allowances (DRA) on a per capita basis while the "deficit" nations are increased to this level. Overall, the total export demand for food falls by 38.6 percent compared to Alternative A. The export mix under this alternative has been shifted considerably. Because of the upgrading of the low income diets, emphasis is placed on wheat exports.[26] Also, the foreign exchange situation in many developing countries does not allow imports of feed grains for the beef feeding industry. However, significant quantities of feed grains are consumed directly by humans rather than by animals.

Total production of wheat increases 159.7 million bushels over Alternative A, reflecting an increase in wheat export demand. Feed grains decrease by 24.3 percent to 198.3 million tons compared to Alternative A. Diminished domestic meat consumption, combined with

[26]Although a majority of the food-deficit nations do not consider wheat as a staple food, the shift toward an increase in wheat consumption is not unlikely if circumstances call for it, similar to the shifts in Indian and Japanese diets.

smaller export demand for grains decreases the area under cultivation by 28.7 million acres. A total of 36.6 million acres are idled under this alternative.

Because of U.S. agriculture's flexibility in wheat production, the wheat yield increases 3.8 percent over that of Alternative A. Yields for feed grains and soybeans increase by 1.6 percent and 10.6 percent, respectively. However, both cotton and silage yields decline slightly.

Silage is the only endogenous commodity that is locationally fixed in this model; i.e., the model does not allow for interregional transportation of silage, which may lead to inefficiencies in silage production.

Alternative C, demand and nutritional requirements

Under Alternative C the consumers in countries with per capita incomes higher than \$600 are allowed to consume at levels dictated by economic variables, whereas those countries below the \$600 per capita income bracket are forced to consume at DRA levels (World Bank, 1973). It follows that total demand for food is necessarily larger than under actual 1980 demand or Alternative B. Hence, demands for U.S. exports are much larger than is possibly feasible given 1980 technology and production capacity. The U.S. export mix is the same as in the previous alternative.

Total wheat production is 2.6 billion bushels, up 13.8 percent over Alternative A and almost 40 percent over the 1973-75 average wheat production levels. The large increase is because of the additional demand for wheat generated by the "poor" countries to upgrade the diet to standard levels. Feed grain production, 243 million tons, is up considerably from the previous level (Alternative B) but is almost 19 million tons lower than the level of production in Alternative A because of the new wheat-feed grains ratio. The demand for feed grains in the developed countries is the main cause for the increase over Alternative B. Soybean production is 1,454 million bushels, an increase of almost 39 million bushels over Alternative A production.

Total land use in this alternative is nearly the same as in the base alternative, 250.3 million acres. The wheat area has increased almost 10 million acres, to accommodate the additional wheat export demand. Feed grains decrease more than 9 million acres. The remaining commodities remain relatively constant compared to Alternative A.

Except for cotton, yields increase slightly over the base alternative. Cotton yield decreases by 3 pounds per acre. Even though wheat production increases almost 14 percent, wheat yield increases slightly, indicating the enormous capacity of U.S. agriculture to grow wheat, especially in the Great Plains.

Alternative D, worldwide crop failure and nutritional requirements

Alternative D simulates a situation in which the world experiences a modest setback in production of about 5 percent. Consumption levels are set at DRA levels for every country while U.S. exports emphasize wheat exports.

Despite the decrease in world production, reduced consumption relative to Alternative A makes up for part of the shortfall. The remainder is supplied by the United States.

Wheat production is 3.1 billion bushels, compared to 1.9 billion bushels for the 1973-75 average and the record 2.1 billion bushels for the 1975-76 crop season. Because of the emphasis on wheat exports, feed grains are 212.4 million tons, up 16 million tons from the 1973-75 actual levels but 40 million tons less than Alternative A. Soybean production increases 14 percent over the base alternative. Soymeal (in the form of texturized vegetable protein) and soyoil are important sources for both calories and protein in the diet of the deficit countries.

Nearly all available land is utilized for the endogenous commodities. The wheat area is 33 percent larger than under Alternative A and makes up 36 percent of total arable land in the model. The feed grain area is down 23 million acres from the base alternative. Even though soybean exports increase considerably under Alternative D compared to Alternative A, the area involved stays relatively constant. Because of the decreased domestic meat consumption, total production of soybeans increases proportionately less than exports do. Cotton production and acreage change relatively little. Small changes in acreage and yields occur because of the spatial allocation of crops among alternatives as domestic demands and exports change. Silage production drops in this circumstance because of the decrease in meat consumption. Fewer cattle are now on feed, resulting in less silage fed.

Wheat and feed grain yields increase marginally. Soybean yield increases 4.4 percent, even though both production and acreage are larger than under Alternative A. It seems that soybeans compete with feed grains for the same land while wheat production occurs mainly on continuous wheat land. Only in the case of large export demands will wheat encroach land usually planted to feed grains or soybeans.

Alternative E, 25-percent reduction in meat consumption in industrialized countries[27]

Alternative E assumes that the developed countries will voluntarily or otherwise reduce normal meat consumption by 25 percent. This assumption implicitly takes for granted that such a cutback will not (on the average) impair the health of the citizens in the countries concerned. Consumption levels are otherwise equal to those under Alternative C; a mix of demand and nutritional requirements. This scenario implements the frequent suggestions of the popular press and many other opinion leaders. These leaders argue that beef consumption is wasteful of scarce resources insofar as the meat is partly or wholly produced on feed grains and other concentrates. They stress that for every pound of meat seven pounds of feed grains are needed. The fact of the matter is that the ratio of beef to feed grains is not 1:7 but rather 1:3 (Peterson, 1975). The average world grain-meat ratio is estimated to be 1:3.55 (U.S. Department of Agriculture, 1970).

[27]The following countries are included: United States, Canada, Japan, The European Community, Spain, Portugal, Norway, Sweden, Switzerland, Greece, Austria, South Africa, New Zealand, and Australia.

Under Alternative E wheat production is 32 percent greater than Alternative A. Wheat production requires almost 89 million acres of total arable land, while yield increases one-half bushel per acres. Feed grain production remains at relatively low levels, particularly because of the reduction in meat consumption. Production is 45 million tons less than in the base alternative while the area in feed grain production declines by more than 19 percent. The difference is accounted for by an increase in feed grain yield of more than 2 bushels per acre. The decrease in feed grain exports is mainly the effect of reduced beef production in the developed feed grain-importing countries. On the other hand, the increase in soybean production and exports accounts for an increase in soybean consumption in the developing and importing nations. Soybean yield increases by more than one bushel per acre to 31.89 bushels. Cotton production has not changed significantly. Silage production decreases 18 million tons because of the decreased demand for beef. Acreage decreases accordingly and yield stays constant.

Alternative F, crop failure and soy protein substitution

In case of major grain crop shortfalls (15 percent below trend level) in the major grain producing and export nations,[28] it is proposed that the world population reduces meat consumption by 25 percent, but it must substitute an equivalent amount of soy protein to replace the animal

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[28] Included are Canada, France, South Africa, Argentina, Australia, and Russia.

protein. The consumption level is again set at the mix of demand and DRA levels. This alternative does not require a reduction in either calories or proteins, but it does require that the consumer increase soy protein intake.

Wheat production is 2.1 billion bushels, 8 percent less than the base alternative. Feed grain production is 47 million tons less than in the base alternative. Soybean production is up substantially over Alternative A, 150 million bushels. Soybean area increases proportionately less because of a 4.4 percent increase in yield. Soybeans and feed grains compete for the same land. Because feed grain production is down significantly compared to Alternative A, soybeans are produced on some of the area released from feed grain production. Wheat and feed grain production release almost 28 million acres, but soybean production acquires an additional 5.5 million acres.

Regional Distribution of Production

The linear programming solution supplies reams of data on a producing region basis. However, because of space limitations and for reasons of clarity the impact of the alternatives will be reported only for the 10 U.S. farm production regions.

In the previous section, the results of the six alternatives were presented at the national level. Variables such as total production, land use, and yields are of primary interest to policy makers and other end-users. However, each of the alternative futures also provokes changes at the more disaggregate level of the 10 farm production regions

(Figure 4.1). Indeed, some of the changes proposed may drastically alter the production pattern within and among regions. Rural communities may benefit or may be adversely affected by such changes.

Because of rounding errors, the national acreages presented in Table 5.2 may vary slightly from those of Table 5.1. Tables 5.3 through 5.7 present the acreage requirements for each of the individual crops at the regional level. The acreage estimates of Tables 5.2 through 5.7 do not include acreages from the White Areas,[29] but the estimates of Table 5.1 do include White Areas.

Alternative A

On a national scale Alternative A requires 9 million acres more than were harvested in 1973-75. This increase, however, is concentrated in four regions (the Corn Belt, the Northern Plains, the South East, and the Southern Plains). The Mountain region and North East region have a decrease in land requirements. The Corn Belt has the largest single increase in acreage (17 million acres) in feed grains, while it reduces wheat and soybean acres (2 million acres and 10 million acres, respectively).

Alternative B

The reduced exports called for under Alternative B, together with decreased domestic demands, result in 27 million acres being taken out of production compared to Alternative A. This decrease in acreage is not

[29] White Areas are defined in Chapter IV.

Table 5.2 Estimates of total harvested acres for all crops for the model alternatives for the United States and for each of the 10 farm production regions with 1973-75 figures for comparison

	1973-75 Actual[a]	Model Alternatives					
		A	B	C	D	E	F
	(thousand acres)						
United States	241,224.4	250,374.7	213,654.3	250,542.1	249,243.4	248,666.5	227,060.2
North East	6,790.7	4,372.1	2,805.8	4,048.7	4,372.1	4,372.1	2,806.7
Corn Belt	68,698.5	75,057.0	70,412.0	75,690.3	75,057.0	75,057.0	73,664.3
Lake States	27,492.3	26,263.4	25,486.3	26,263.4	26,263.4	26,263.4	25,564.7
Appalachia	11,346.0	7,154.1	5,128.4	7,497.1	8,419.4	8,518.4	5,625.1
South East	5,111.7	8,705.8	4,286.7	8,807.2	8,705.9	8,705.9	6,689.1
Delta States	13,142.6	13,226.5	10,809.8	13,668.9	13,226.5	13,226.6	12,131.4
Southern Plains	25,255.7	29,003.4	26,646.7	28,972.0	28,971.9	28,971.9	27,086.9
Northern Plains	55,615.7	62,696.1	47,446.9	56,647.9	61,732.54	61,800.5	53,133.5
Mountain	18,832.9	15,788.2	13,954.1	15,788.2	15,788.2	15,788.2	13,662.8
Pacific	9,219.2	7,189.4	6,697.7	6,697.6	6,688.6	6,697.6	6,697.6

[a] SOURCE: U.S. Department of Agriculture, 1976e .

Table 5.3 Estimates of harvested acres for wheat for each of the model alternatives for the United States and for each of the 10 farm production regions with 1973-75 figures for comparison

	1973-75 Actual[a]	Model Alternatives					
		A	B	C	D	E	F
		(thousand acres)					
United States	63,046.00	68,708.94	70,756.49	78,185.04	91,534.13	88,725.66	61,517.53
North East	719.01	193.27	193.27	326.71	787.83	706.64	193.27
Corn Belt	5,394.67	3,946.32	5,849.65	6,248.47	8,448.86	8,135.62	5,601.06
Lake States	3,458.00	4,560.13	11,492.46	6,198.82	9,811.80	9,548.61	5,900.23
Appalachia	1,076.00	1,425.52	463.42	1,608.89	2,500.34	2,466.82	330.10
South East	420.67	1,473.89	378.16	1,377.21	2,229.17	2,086.06	354.02
Delta States	552.33	3,563.97	4,605.54	4,079.91	4,741.02	4,756.18	2,899.63
Southern Plains	10,253.33	10,113.26	11,312.65	11,506.28	13,331.72	11,964.54	8,624.19
Northern Plains	26,833.33	31,043.60	23,544.25	32,876.99	34,473.99	33,869.00	25,519.37
Mountain	9,449.33	7,990.80	8,426.56	9,512.69	10,710.92	10,702.47	7,684.13
Pacific	4,890.00	4,398.18	4,490.53	4,449.07	4,498.47	4,489.90	4,411.54

[a]SOURCE: U.S. Department of Agriculture, 1976e .

Table 5.4 Estimates of harvested acres for feed grains for each of the model alternatives for the United States and for each of the 10 farm production regions with 1973-75 figures for comparison

	1973-75 Actual[a]	Model Alternatives					
		A	B	C	D	E	F
				(thousand acres)			
United States	102,540.33	112,385.81	83,740.55	103,062.51	89,083.16	90,963.62	91,987.49
North East	4,024.33	2,439.27	1,120.95	2,326.41	2,075.53	2,125.65	1,120.95
Corn Belt	36,716.66	53,345.88	43,813.68	49,809.41	45,462.95	46,307.80	44,778.83
Lake States	18,058.67	15,692.99	8,298.36	12,475.22	8,650.04	8,895.10	11,123.01
Appalachia	4,351.02	1,750.40	1,190.03	1,582.67	1,516.95	1,615.95	1,190.03
South East	3,652.01	1,262.04	1,262.04	1,262.04	1,262.04	1,262.04	1,262.04
Delta States	564.33	222.78	222.78	222.78	222.78	222.78	222.78
Southern Plains	9,207.00	10,351.17	8,743.75	10,146.20	10,035.27	10,063.11	10,844.98
Northern Plains	23,041.35	20,686.80	14,627.86	20,125.19	15,836.70	16,588.60	16,540.38
Mountain	4,705.01	5,899.61	3,726.23	4,377.72	3,286.01	3,276.70	4,169.61
Pacific	2,283.00	735.74	735.74	735.74	735.74	735.74	735.74

[a]SOURCE: U.S. Department of Agriculture, 1976e.

Table 5.5 Estimates of harvested acres for soybeans for each of the model alternatives for the United States and for each of the 10 farm production regions with 1973-75 figures for comparison

	1973-75 Actual[a]	Model Alternatives					
		A	B	C	D	E	F
	(thousand acres)						
United States	53,923.33	45,902.33	37,211.48	46,010.74	46,800.44	46,906.44	51,411.84
North East	625.00	468.11	450.17	468.11	468.11	468.11	417.79
Corn Belt	24,579.34	15,056.09	18,324.96	16,300.24	18,726.94	18,148.85	20,813.91
Lake States	3,647.33	2,590.15	2,682.24	4,257.21	4,788.37	4,738.61	5,466.57
Appalachia	4,672.00	3,425.65	1,234.05	3,073.99	2,233.11	2,244.96	1,920.85
South East	3,409.33	4,700.06	1,793.11	4,725.01	4,135.27	4,251.84	4,213.71
Delta States	9,060.00	7,803.74	4,573.54	7,480.91	6,742.42	6,741.86	7,598.40
Southern Plains	570.67	3,861.39	1,566.86	2,641.83	951.85	2,287.11	2,641.83
Northern Plains	2,862.33	7,997.14	6,586.55	7,063.4	8,754.38	8,025.11	8,338.77
Mountain	--------	---------	--------	--------	---------	---------	---------
Pacific	--------	---------	--------	--------	---------	---------	---------

[a] SOURCE: U.S. Department of Agriculture, 1976 e .

Table 5.6 Estimates of harvested acres for cotton for each of the model alternatives for each of the model alternatives for the United States and for each of the 10 farm production regions with 1973-75 figures for comparison

	1973-75 Actual[a]	Model Alternatives					
		A	B	C	D	E	F
		(thousand acres)					
United States	11,199.03	10,035.45	10,198.51	10,089.16	10,082.30	10,083.26	10,134.52
North East	---------	---------	---------	---------	---------	---------	---------
Corn Belt	237.84	148.61	148.61	148.61	148.61	148.61	148.61
Lake States	---------	---------	---------	---------	---------	---------	---------
Appalachia	548.33	1,103.40	1,519.62	1,439.43	1,439.43	1,439.43	1,439.43
South East	1,050.43	944.70	559.87	906.38	788.59	809.41	559.87
Delta States	2,841.67	1,495.85	1,283.77	1,302.74	1,396.09	1,378.84	1,283.77
Southern Plains	5,022.00	4,385.05	4,754.17	4,385.05	4,385.05	4,385.05	4,702.54
Northern Plains	---------	---------	---------	---------	---------	---------	---------
Mountain	408.02	902.56	902.56	902.56	902.56	902.56	902.56
Pacific	1,018.57	1,055.28	1,029.91	1,004.39	1,021.97	1,019.36	1,097.74

[a]SOURCE: U.S. Department of Agriculture, 1976e .

Table 5.7 Estimates of harvested acres for silage for each of the model alternatives for the United States and for each of the 10 farm production regions with 1973-75 figures for comparison

	1973-75 Actual[a]	Model Alternatives					
		A	B	C	D	E	F
	(thousand acres)						
United States	10,515.66	13,342.79	11,756.23	13,194.55	11,733.68	11,987.50	12,008.82
North East	1,422.32	1,271.46	1,041.36	1,250.87	1,040.64	1,071.70	1,073.74
Corn Belt	1,770.00	2,560.11	2,275.10	2,550.28	2,269.65	2,316.13	2,321.94
Lake States	2,328.33	3,420.16	3,013.22	3,332.19	3,013.23	3,081.12	3,074.88
Appalachia	698.67	860.35	721.23	860.35	729.53	751.19	744.65
South East	231.33	325.19	293.55	325.19	290.80	296.53	299.47
Delta States	124.30	140.20	124.14	140.20	124.22	126.88	126.80
Southern Plains	202.66	292.57	269.23	292.57	268.04	272.12	273.32
Northern Plains	2,878.67	2,968.54	2,688.28	2,939.40	2,667.47	2,712.80	2,734.99
Mountain	598.32	995.25	888.72	995.25	888.72	906.48	906.48
Pacific	1,024.66	508.36	441.38	508.36	441.38	452.55	452.55

[a] SOURCE: U.S. Department of Agriculture, 1976e .

spread uniformly throughout the regions but is concentrated in five farm production regions: the Corn Belt, the South East, Mountain, the Southern Plains, and the Northern Plains. The latter region accounted for more than 15 million acres withdrawn from production. Because of the reduction in exports and domestic demands, the nation's land base adjusts its mix of crops produced in each region. Wheat production in the Northern Plains is reduced by 8 million acres and feed grains require 6 million acres less than under Alternative A. The Lake States and the Corn Belt both increase wheat acreage (4 million acres and 7 million acres, respectively), but at the same time, land requirements for feed grains reduce by 10 million and 7 million acres, respectively. The Corn Belt also requires 18 million acres for soybean production, 3 million more than under the base alternative. The additional acreage is required because of reductions in acreage in the Appalachia, the South East, and Delta States regions. Silage acreage reduces in those regions where it is produced.

Alternative C

Increased exports cause pressures on the model's land base, resulting in shifts among the 10 regions. The nation's land base is fully utilized as under the base alternative. On the farm production region level shifts occur in the Corn Belt, the Lake States, the Southern Plains, and the Northern Plains. For feed grains the Corn Belt would require 4 million more acres, while wheat would command an additional 2 million acres compared to Alternative A. Soybean production increases in both the Corn Belt and the Lake States by 1.2 and 1.7 million acres, respectively. The Southern Plains would require 1.9 million acres less than under the base alternative. Except for small changes in acreage the area required for cotton production does not vary much among alternatives because of fixed exports imposed upon the model.

Alternative D

Alternative D again exhausts the nation's land base, while wheat exports are emphasized. The Appalachia region and the Northern Plains increase total harvested acres. Wheat acreage under Alternative D increases by 22.8 million acres, while feed grain acreage decreases by 23.3 million acres. The Corn Belt and the Lake States both double wheat acreage. The Appalachia, South East, the Southern Plains, and Northern Plains regions also have increases in wheat acreages of smaller magnitudes than under the previous alternative.

Feed grain acreage is reduced in the Corn Belt and Lake States regions by more than the increase in wheat acreage in those regions. The remainder of the feed grain acreage is used by soybean production.

Wheat acreage is expanded in the Northern Plains (3.4 million acres) while feed grain production is reduced by 4.8 million acres. Soybean production requires most of this area.

Alternative E

Because of the total usage of the nation's land base, shifts among regions are relatively minor under this alternative and trade-offs within regions are small compared to Alternative D.

Alternative F

Under this alternative production utilizes only 227.1 million acres for the nation's commodity demands. The North East, Appalachia, Northern Plains, and Mountain regions take the major burden of production cutbacks. The idled areas must be considered as marginal production regions, brought into production only when other, more competitive regions are already drawn into production and with demands not yet satisfied. In the Corn Belt and Lake States regions additional wheat acreage is obtained from feed grain area. Soybean production in the Corn Belt increases by 5.8 million acres while the Lake States acreage more than doubles to 5.5 million acres. Nationally, wheat acreage is down 7.2 million acres, and feed grain acreage is down 10.4 million acres because of reduced export demands. Soybean exports are up, however, resulting in an additional 5.5 million acres in soybean production.

Supply Prices

For each model alternative the programming model generates a set of prices that are necessary to cover the costs incurred to bring forth the output demanded in each alternative. The national supply price is not a weighted average for all producing regions. Rather, the model (assuming perfect competition) chooses that producing region which is selected last to come into production for a particular crop (and thus, has the highest cost of production) to satisfy demand. The cost of production of the particular crop in the specified region is then selected (abstracting from price differentials because of transportation costs) as the supply price. In those producing regions that are selected to come into the solution at an earlier point, the difference in the production cost and the national supply price is attributed to the land as a residual return.

Table 5.8 presents the estimated supply prices for each crop for each alternative. The upper part of the table reflects the supply prices in constant 1972 dollars ; the lower part of the table presents the supply prices in 1975 prices. The 1975 prices are inflated using an index constructed from prices paid by farmers for farm inputs (U.S. Department of Agriculture, 1976a). The prices in Table 5.8 present the price at the farm level. Thus, no allowance is made for transportation costs between demand regions.

Alternative A

Alternative A farm prices for wheat and soybeans are slightly lower than the 1973-75 average deflated farm prices but higher than the 1975 farm prices. The feed grain price for the base alternative is slightly higher than both the 1973-75 average price level and 1975 price levels. The cotton price at 56.3 cents per pound is estimated to be 23 percent higher than the 1973-75 price level at 45.8 cents per pound but only 12 percent higher than the 1975 price of 50.1 cents per pound.

No national actual average price is available for silage. Therefore, silage prices will be compared to the base alternative in the remaining situations.

Table 5.8. Estimated supply prices for the endogenous commodities for all alternatives with 1973-75 and 1975 prices for comparison

A 1972 prices	1973-75 Actual[a]	Model Alternatives						
		1975	A	B	C	D	E	F
Wheat ($/bu.)	2.55	2.34	2.48	1.66	2.38	2.38	2.37	1.68
Feed grains ($/ton)	1.70	1.65	1.74	1.12	1.60	1.53	1.52	1.20
Soybeans ($/bu.)	3.76	3.06	3.71	2.08	3.34	3.13	3.13	2.34
Cotton (¢/lb.)	0.305	0.333	0.374	0.339	0.370	0.370	0.370	0.338
Silage ($/ton)	-	-	12.43	9.38	11.75	11.58	11.52	9.68
B 1975 prices[b]								
Wheat ($/bu.)	3.84	3.52	3.73	2.50	3.58	3.58	3.56	2.53
Feed grains ($/ton)	2.55	2.48	2.62	1.68	2.41	2.30	2.29	1.80
Soybeans ($/bu.)	5.66	4.60	5.58	3.13	5.02	4.71	4.71	3.52
Cotton (¢/lb.)	0.458	0.501	0.563	0.500	0.557	0.557	0.557	0.508
Silage ($/ton)	-	-	18.70	14.11	17.67	17.42	17.33	14.56

[a] SOURCE: U.S. Department of Agriculture, 1976a.

[b] The deflator is developed from the "prices received - prices paid" index. U.S. Department of Agriculture, 1976a. Factor = 1.5041.

Alternative B

In Alternative B more than 37 million acres are idled because of low export demands. Consequently, supply prices fall relative to Alternative A. In spite of the emphasis on wheat exports, the wheat price only drops 33 percent. The feed grain price and soybean price fall 36 percent and 44 percent, respectively, to $1.68 and $3.13 per bushel (in 1975 prices). The cotton price under Alternative B is unchanged from current cotton prices but down 6.3 cents from the base alternative. Because of the reduction in domestic calorie intake, beef consumption decreases, resulting in lower silage production and a 25-percent drop in silage prices.

Alternative C

The scenario in Alternative C calls for extremely high exports, resulting in high supply prices. However, because of the change in export mix (of wheat, feed grains, and soybeans) towards a higher proportion of wheat exported relative to the base alternative, the great potential of U.S. agriculture to produce wheat results in supply prices considerably lower than those in Alternative A. The wheat price drops by 15 cents per bushel, the feed grain price by 19 cents per bushel, and the soybean price by 56 cents per bushel. Cotton remains relatively constant compared to the base alternative. Silage drops more than $1.00 per ton.

Alternative D

Supply prices are generally much lower under this alternative, again because of the shift away from feed grains and to wheat. Although the cotton price remains relatively constant, the silage price drops 7 percent. Feed grains and soybeans dropped to $2.30 and $4.70 per bushel, down 32 cents and 85 cents per bushel, respectively.

Alternative E

The estimated supply prices under Alternative E are almost identical to those of Alternative D. Export requirements were only marginally different for the various export crops.

Alternative F

The supply prices under Alternative F drop sharply from those under the base alternative. The idled land in this situation reduces prices by 32 percent, 31 percent, and 37 percent for wheat, feed grains, and soybeans, respectively. Cotton drops only 10 percent or 0.06 cents per pound. The silage price dropped again because of reduced meat consumption.

Exports

Because export demands are of major importance in this study, the estimates will be presented in this section. The demand for exports of wheat, feed grains, and soybeans are derived using methods as outlined in the previous chapter.

Historically, the developing countries have not been able to meet nutritional requirements in the form of daily recommended allowances.

On the other hand, the developed nations have consistently "over-consumed" since the period after World War II.

Table 5.9 provides an indication of how per capita supplies of calories and protein have developed for a number of world regions.[30] In all regions the per capita supply of both calories and protein has increased. Using 1936-38 as a base, Europe has increased its per capita calorie and protein supply by 16 percent and 19 percent--more than any other region. However, Latin America has the absolute highest amount of calories on a per capita basis, whereas the United States is the largest supplier of protein.

A detailed set of energy (calorie) requirements are estimated for 17 sex and age classes. Applying a constant growth rate to the mid-1976 population estimates (incorporating 1973 demographic distributions) calorie requirements were estimated for 17 world regions. Tables 5.10 and 5.11 indicate the requirements: a) Table 5.10 reflects the calorie requirements based on daily recommended allowances and b) Table 5.11 shows the demand requirements for 1980.

The nutritional requirements can be satisfied by all foods, as long as the diet is well-balanced. In this model any domestic deficit in calories can be made up for by imports of wheat, feed grains, and soybeans from the United States.

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[30] Note that per capita supply is not meant to be the same as per capita consumption nor is it intended to indicate a national average. It is merely an indication of available supplies at one point in time and abstracts from all economic variables that govern demand. It is, therefore, biased upward.

Table 5.9. Historical trends in per capita calorie and protein supplies

Region	Calories Per Person Per Day 1934-38 level[a]	1934-38 = 100 1948-52 Index[a]	1957-59 Index[a]	1969-71 Index[b]	Total Protein Per Person Per Day 1934-38 Level[a]	1948-52 Index[a]	1957-59 Index[a]	1969-71 Index[b]
Far East (including China)	2,090 cal.	90	99	102	61 grams	89	92	92
Near East	2,295 cal.	97	108	109	72 grams	96	106	97
Latin America	2,160 cal.	107	116	117	64 grams	97	105	102
Europe (including USSR)	2,870 cal.	96	106	111	85 grams	96	104	114
North America	3,260 cal.	97	95	102	86 grams	106	108	122
Oceania	3,290 cal.	99	99	99	103 grams	95	91	105
World	2,380 cal.	94	102	104	67 grams	93	99	103

[a]SOURCE: Cesal, Blakeslee, and Heady, 1963.

[b]SOURCE: Food and Agriculture Organization, 1971, United Nations, 1974a.

Table 5.10. Population and caloric requirements for 17 world regions excluding United States

Region Number	Region Name	1970 Population	1980 Population	Calorie Requirement for 1980 (10^9)(DRA)
1	Canada	23.1	24.2	21,250.4
2	Mexico	62.3	71.5	51,827.4
3	Central and South America	118.8	133.2	109,060.4
4	Brazil	110.2	121.7	100,443.8
5	Southern America	28.5	30.0	26,134.3
6	Africa	355.4	393.2	316,989.1
7	South Africa	25.6	28.0	24,074.3
8	Northern Europe	234.6	241.7	212,480.7
9	Southern Europe	131.3	135.4	119,577.7
10	East Bloc Countries	109.5	155.1	137,668.8
11	USSR	257.0	264.4	222,081.2
12	Middle East	137.2	147.1	124,143.1
13	Central Asia	796.2	828.7	687,235.3
14	Southeast Asia	393.6	422.6	347,853.2
15	P.R.C.	836.8	930.4	797,862.3
16	Japan	112.3	117.9	104,880.3
17	Oceania	17.0	18.1	15,668.1
18	World Total	3,749.4	4,063.2	3,419,230.3

Table 5.11. Population and consumption demand in terms of calories and proteins for 17 world regions for 1980

Region Number	Region Name	1980 Population (10^6)	Total Calories (10^9)	Total Protein (10^6)	Animal Calories (10^9)	Animal Proteins (10^6)
1	Canada	24.2	28,195.6	881.7	127.2	594.2
2	Mexico	71.5	70,386.3	1,758.4	91.7	456.3
3	Central and South America	133.2	115,253.3	2,886.6	13.0	75.4
4	Brazil	121.7	122,507.3	3,072.8	145.8	928.2
5	Southern America	30.0	26,801.3	212.6	26.9	154.2
6	Africa	393.2	337,382.6	10,021.3	6.2	54.7
7	South Africa	28.0	29,056.7	835.8	62.6	323.6
8	Northern Europe	241.7	302,558.4	8,854.8	1,152.5	5,430.5
9	Southern Europe	135.4	153,432.0	4,620.2	294.6	2,043.6
10	East Bloc Countries	155.1	184,895.8	5,338.6	597.4	2,565.4
11	U.S.S.R.	264.4	318,491.1	9,424.1	770.5	4,094.8
12	Middle East	147.1	137,189.0	3,799.2	148.3	871.1
13	Central Asia	828.7	674,011.1	17,278.9	414.0	2,118.7
14	Southeast Asia	422.6	346,406.0	8,242.2	152.3	1,306.6
15	P.R.C.	930.4	743,005.6	21,156.0	634.1	3,046.1
16	Japan	117.9	116,498.9	3,577.6	106.5	1,180.2
17	Oceania	18.1	21,788.9	669.2	100.7	449.7

Alternative A

The base alternative (in which the land base is totally used) allows exports to increase substantially above the high export levels of recent years (1973-75). Relative to Alternative A, wheat exports increase 500 million bushels to 1,688 million bushels. Feed grains increase 48 percent to 59.1 million tons. Soybeans increase 204 million bushels to 690 million bushels (Table 5.12). The export of cotton is fixed at 4.2 million bales under all alternatives. Of course, corn and sorghum silage is not an export item.

The effect exports have under the base alternative are such that starvation will still exist but will affect less people relative to the pr present. It is estimated that 375 million people (compared to 400-500 million at present) will be starving because of a grain shortage of approximately 58 million metric tons (Table 5.13).

Alternative B

Under this alternative the wheat exports are emphasized. In addition, a worldwide diet at DRA levels is prescribed. The result, if such a policy is implemented, is rather astonishing. Wheat exports, up 9.4 percent over Alternative A, increase 159 million bushels. Feed grains decrease 23 million tons. This can be partly attributed to the diminished demand for meat in importing countries. Soybeans, however, increase 193 million bushels. And while starvation is wiped out, 36 million acres in the United States are withdrawn from production under this alternative.

Table 5.12. Estimated exports for endogenous commodities for each model alternative with 1973-75 exports for comparison

	1973-75 Actual[a]	Model Alternative A	B	C	D	E	F
				(millions)			
Wheat (bu.)	1,188.9	1,688.4	1,847.8	2,007.0	2,497.3	2,410.8	1,506.3
Feed grains (tons)	39.9	59.1	36.3	43.5	54.1	52.2	49.4
Soybeans (bu.)	485.7	689.8	672.7	730.7	909.2	877.7	1,035.6
Cotton (bales)	4.8	4.2	4.2	4.2	4.2	4.2	4.2

[a]SOURCE: U.S. Department of Agriculture, 1976 j.

Alternative C

Alternative C assumes a mixed demand-DRA consumption structure. Export levels of all three commodities increase over those of the base alternative because of an increased demand for food of the starving peoples in the various regions. Wheat exports are 2,007 million bushels, up 18.9 percent over Alternative A exports. Feed grain exports are down by 16 million tons from Alternative A, mainly because of the change in the wheat-feed grains mix. Soybeans again are up 6 percent. Exports are now 730 million bushels, contributing to the calorie requirements and providing a great amount of protein in the form of soybean oil or soybean meal isolates or concentrates.

Because the world food requirements are at their highest under this alternative, the food deficit is at a maximum. A food gap of 113 million metric tons resulting from this high demand alternative translates to approximately 732 million people starving to death.

Table 5.13. Demand requirements, export supply and number of people suffering from malnutrition

	PRESENT	Model Alternatives A	B	C	D	E	F
Exports demanded (billion KCAL)		600,745.1	368,796.0	801,136.1	579,018.7	594,016.9	362,697.9
Exports supplied (billion KCAL)		395,551.5	368,796.0	400,568.1	498,426.8	481,153.7	362,697.9
Number of people starving (approx. in millions)	400-500[a]	375.	-	732.	147.	206.	-
Deficit of grain (million metric tons)		57.7	-	112.7	22.7	31.7	-
U.S. idle land (million acres)		0	36.3	0	0	0	24.1

[a] SOURCE: U.S. Department of Agriculture, 1974d.

Alternative D

Adverse weather conditions in the rest of the world lead to greater import demands from the United States. United States agriculture must produce "fence-row to fence-row" to satisfy demand and even then there still exists a food shortfall of 23 million metric tons of grains. It is estimated that 147 million people will suffer from hunger and malnutrition under this situation. Wheat and soybean exports in this situation increase by 48 percent and 32 percent, respectively. Feed grains, on the other hand, are still down 5 million tons from the base alternative because of the change in the wheat-feed grains mix.

Alternative E

Under this scenario it is assumed that the "rich" countries will reduce consumption of meats by 25 percent. It is assumed that the loss of protein is not detrimental to the health of the average person. Wheat exports are up 722 million bushels to 2,410 million bushels. Soybean exports increase 278 million bushels, up 27 percent from the base alternative. The increase in soybean exports is possible because of reduced home consumption. Feed grains are down slightly. Notwithstanding this offer brought by the "well-to-do," the food deficit is not eradicated. It is estimated that shortfall of almost 32 million metric tons remains, which leads to about 206 million people starving.

Alternative F

Adverse weather conditions in the major producing and exporting countries lead to a 15 percent below-trend reduction in yield of wheat, feed grains, and soybeans. To compensate for such a shortfall, all nations reduce meat consumption by 25 percent and substitute soy protein for the amount of animal protein lost. Thus, in this situation the amount of protein consumed remains the same but the composition is altered. Substantial savings in grain are made under such an assumption. Import demands for wheat and feed grains decrease substantially. Wheat exports are 1,506 million bushels, down 11 percent from the base alternative level. Feed grain exports are down 16 percent. Soybean exports, of course, increase greatly because of the shift in world demand. Soybean exports are 1,036 million bushels, up 336 million bushels compared to Alternative A (a 50 percent increase). Under this assumption world hunger can be eradicated. United States agriculture keeps idle about 24 million acres, but all domestic and foreign demands are satisfied.

CHAPTER VI. POLICY RECOMMENDATIONS

Mankind is faced with food shortages for the next decade. In spite of the goals under the Second Development Decade or the United Nations Indicative World Plan of Action, food to the hungry people of the world will not be available in any greater quantities in the next decade than it has been in the past decade. The two main reasons for such a gloomy future are: a) the high population rate of growth in the developing countries that negates the relatively high production rate of growth in most of these countries and b) available food is distributed to those who can afford it best, not to those who need it most.

It is predicted that in the next decade the per capita supply of food will decline in many regions but will hold steady or slightly increase in others. The regions most susceptible to food shortages are those that have a per capita income of less than $200. More than 60 percent of the population in the developing countries belong in the category of incomes less than $200. Projections indicate that these people are likely to incur about 50 percent of the food deficits reported earlier (International Food Policy Research Institute, 1976).

It is not difficult to imagine that financing imports of such magnitude will create foreign exhange problems beyond any prospect of solution, not to mention the physical transportation problems to get food to deficit areas.

It is in this light that the Rome Food Conference in 1974 proposed to form a World Food Council that is charged with the formulation of a world food policy acceptable to both donor and recipient nations.

World Food Policy

Any food policy formulation that involves a multitude of sovereign nations is bound to create problems in terms of whose wishes and priorities are to be included. From economic theory we know that difficulties exist in aggregating preferences through the voting mechanism,known as Arrow's paradox (Tweeten, 1970). No food policy can reflect all wishes of both donor and recipient nations. There exists, however, considerable danger that those who have surplus food will tend to impose their individual wishes upon those who are at the receiving end.

Donor country policies

The making of a food policy must begin with an understanding of aspirations that people hold regarding the issues; how do people think things out to be (Hathaway, 1963). For a food policy consensus must somehow be reached. A continuous struggle between producer and consumer lobbies with legislators will eventually lead the legislative branch to produce a policy reflecting the priorities of the people.[31] In general, a food policy must be acceptable to four groups: 1) farmers, 2) consumers, 3) taxpayers, and 4) foreign clients.

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[31]It would be interesting to do a study on trade-offs between various priorities, i.e., a goal (or multigoal) programming analysis. If a set of proper weights could be secured, the results would show the effects of different combinations of priorities on agriculture, consumers, and the environment.

The farmers The farmers expect a fair rate of return on their investments and an adequate income, i.e., the farmer should be able to recover the cost of production including a compensation for risk and investment. If strong demand continues, farmers will not encourage the government to get back into agriculture. On the other hand, if once again agriculture is plagued by overproduction, and farmers cannot secure a fair rate of return, the government must be willing to step back into agriculture. In general, the government must provide a bottom in the agricultural product market, but not a ceiling. But if the farmer is asked once again to produce fence-row to fence-row to provide food for a hungry world, a strong (government) market institution must be created that can guarantee a fair return to the farmer.

The consumers The consumer expects adequate food at fair and stable prices. He also expects a reasonable selection of food even if it means importation of such foods. The consumer desires government restrictions on exports (e.g., embargoes on soybeans and wheat), but concomitantly rejects government action when it sets "voluntary" import quotas (such as the recent import quotas on Argentina meat and Italian shoes) for particular commodities. Because in the former case domestic prices will fall, whereas in the latter case domestic prices will rise.

The taxpayers The general public or taxpayers expect the government to formulate policies that encourage an efficient allocation of resources across and within the different sectors of the economy. Therefore, the public will approve allocation of funds to further such a cause through programs that speed up the movement of resources in and out of agriculture, if need be. Society will have maximized benefits minus costs if the social rate of return is equal to the private rate of return at the margin.

The foreign clients Foreign clients expect a source of year-to-year imports. In particular, regular customers must be able to count on U.S. grain exports. On the other hand, not so regular customers (those who must import food because of crop shortfalls, natural disasters, or political disturbances) who can afford to pay for it, must be made aware of the fact that they compete for the grain residual after regular demand is satisfied. Such restrictions need not pose a problem as long as the prospective buyers are made aware of the rules of trade. Also, such a rule may encourage some of the developing countries to keep a small grain reserve on hand that could absorb part of unexpected crop shortfalls or other minor disasters.

It is needless to say that whatever the contents of a policy the fate of millions of people will be decided by it. The policy group must first decide who qualifies for food aid. Depending upon the quantity of food available (in reserve), the countries included must be selected on characteristics such as per capita income, own production capacity, current level of nutrition, and infrastructure. As stated at the outset of this chapter, 60 percent of those who live in developing countries (with per capita incomes of less that \$200 per annum) suffer from undernourishment. The bulk of the food should be channeled to these countries for immediate relief.

Recipient policies

What must recipient countries demand from a food policy? They must put forth a number of requirements ensuring that food aid does not become a burden for those it is supposed to relieve. And again, four groups must be kept in mind: 1) farmers, 2) consumers, 3) taxpayers, and 4) donor nations.

The farmers The farmers must insist that any food aid policy must be defined as a short-run policy and designed to bring relief only for the immediate future (this crop year). They must also insist that the government guarantees a fair return on their investment to encourage production. Food aid must not be allowed to depress local market prices. Indeed, governments must, if necessary, subsidize the farmer so that domestic agricultural production will continue to grow.

The consumers The recipient country consumers demand an adequate supply of food at low prices. They already pay 50-75 percent of their income on food items and, therefore, expect the government to control the price level. As mentioned earlier, to keep food prices low (as many governments do to keep wages low), it may be time to subsidize the farmer and give him the change to respond to the market signs.

The taxpayers In any food aid program the ultimate burden will be on the recipient country. Short of an outright give-away program, any food aid payments will preempt foreign exchange to be used for purposes of economic development. The taxpayer must, therefore, insist that tax funds be first and foremost diverted into areas where an additional dollar of investment pays off the most. In such a context food aid must be defined as a short-run phenomenon. Again, society must maximize benefits such that the social rate of return is equal to the private rate of return at the margin.

The donor nations Recipient countries must require that all food aid received in whatever shape or form must be without strings attached.

Who decides?

Formulating a food policy acceptable by all is a tedious task. Who must decide these issues? Currently the UN-sponsored World Food Council is charged with this responsibility. But concomitantly there exist numerous bilateral and multilateral agreements that provide for aid based on a number of considerations not necessarily reflecting the greatest need, but economic or other issues. For example: 1) in case of barter where the food-deficit country may have a scarce natural resource; 2) military interests, or 3) friendship or other treaties.

The individual food aid efforts must be pooled so that the food surplus of the exporting countries can be spread more equally. It appears to me that the UN's FAO must be granted the task of developing and creating an institution (led by independent experts) that can set world food policy and develop formulas to decide how much, who, what, and when.

Note, however, that such an institution should only concern itself with "soft" sales; i.e., the agency is not allowed to disrupt the commercial market. Indeed, the agency must participate in the world market to secure enough food for its food reserve and must only distribute the food to those who cannot themselves bid away grain from more affluent purchasers.

Who pays?

Any food aid scheme must eventually be paid for. Who must pay? Again the agency must have some commitments of pledged funds from UN members. Commitments could preferably be tied to a certain percentage of gross national income, e.g., 0.25 percent of gross national income of member nations. These funds could then be used to make up the difference between the world market price and the price agreed upon for the particular "soft" sale. Thus, the role carved out for the FAO agency could be that of a large food broker. The agency would buy up quantities of food on the world market and sell it to problem areas if requested to do so by the deficit nations. The FAO would also have the power to decide where it would want to keep its food reserve.[32]

Formulating a policy can only be a succesful endeavor if the policy makers know what the production capacity is of world agriculture. This study has estimated a number of alternatives that are most likely to play a role in the formulation of a world food policy.

What are the possibilities?

The results of the study show that only in two instances (alternatives B and F) can the world be fed at adequate levels with no humans starving.

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[32]For detailed studies on food reserves see Tweeten (U.S. Congress, 1976) and a U.S. Department of Agriculture symposium (1976c).

Any of the remaining alternatives indicate that a goodly number of individuals will suffer from malnourishment for the next decade or so.

The export estimates of wheat, feed grains, and soybeans are in some instances above record levels of recent years (1973-75). However, the study estimates that prices will only increase moderately above current price levels (1973-75). The study shows that American agriculture has enormous capacity for producing food. Changes in production techniques and consumption patterns have not been exhausted by any means. And each grain-saving measure may result in millions of bushels of additional grain for export as reported in Faber, Heady, and Sonka (1976).

Although the model allowed for additional grain-saving measures in all countries, the outcomes of the study are such that only in two cases can the world feed its people, namely 1) if all of the world consumes at DRA levels--rich and poor alike, and 2) if the world reduces its meat consumption by 25 percent and substitute soy protein. One must realize, however, that under both circumstances (alternatives B and F) the policy requirements would be difficult to fulfill; for to force the affluent nations to consume less on a voluntary basis must be considered a rather tedious task. On the other hand, substitution of soy protein for animal protein may be possible if the soy protein-meat price ratio is right.

Again, we should for a moment return to a suggestion made earlier. Because the developing countries cannot bid grain away from the more affluent nations, the FAO agency could act to bid up the price of grain so high that less grain would be used for beef production, resulting in an increase in the grain supply and a decrease in beef consumption.

The rather gloomy food situation seems to contradict what others have said, namely that world agriculture has by no means reached its maximum output using current technology. Indeed, food production to date is greater than current estimated consumption. However, food losses are so large in most developing countries that any deficit can be made up by those losses. Knowledge to date about food losses and post-harvest food losses, in particular, is little and receives little attention. This study found that, depending upon crop and geographic location, food losses vary anywhere between 20 and 50 percent of production (see also Food and Agriculture Organization, 1975). Because few agencies or individuals are aware of the magnitude of the problem, little systematic research has been undertaken to estimate post-harvest food losses by countries.[33]

If the food situation is indeed so gloomy, other steps must be taken to correct the situation. The best way to correct economic diseases is to inject incentives into the right veins. Such injections must almost always be given by the government. The government also develops and formulates agricultural policies. It now must provide the right incentives in its agricultural policy.

[33]Twenty individuals and groups in the United States and Canada, who are supposed to be knowledgeable in the field of post-harvest losses were called. With the exception of two cases, no one could offer any help or worse yet, was even aware that a problem existed. From a recent FAO publication a set of general post-harvest loss estimates were obtained, which were found to be close to what the model indicated.

Agricultural Development Policies

Farm policy-making is a subject many books have been written about. However, in rather abbreviated form, one inclusive set of agricultural policies is quoted below. In Scientific America, Heady wrote:

> What are the specific elements of a successful and conscious agricultural development policy? First, the policy must enlarge the farmer's supply of major resources and keep their prices low. Second, it must keep the prices of the commodities produced on the farm relatively high and stable. Third, it must create a tenure system that structures the operating costs of the farms in a way that is favorable to innovation. Fourth, it must encourage research and technology, and it must maintain an adequate and continuous flow of information to the farmer on the availability of new techniques and technology. The United States has implemented all these elements in its agricultural development policy, sometimes separately, usually in combination with one another. Over the decades the specific methods by which the Government has implemented its agricultural policy have changed, but the general principle of encouragining agricultural development has remained the same (Heady, 1976).

In a nutshell this is an agricultural policy that must be pursued by governments in developing countries who want to build a strong agricultural sector. Although not exhaustive, this set of policies can, of course, be effective only if the government also formulates a general long-run economic policy. Maintaining artificially high prices, as implicitly assumed by Heady, can only last for a short while. Therefore, a good economic income policy also must be implemented so that a high demand will be created and maintained. Sound economic policies may also encourage the developing countries to rely to a lesser extent on self-sufficiency. Self-sufficiency, although a noble concept in its own right, tends to encourage a less than efficient distribution of resources to the various economic sectors.

Some experts predict that ultimately the world can sustain anywhere between 50-60 billion people. Does this mean that the zero population growth is no longer a valid concept? In the short run it certainly still is a valid concept. The world has not yet adapted technology to such an extent that it can even sustain the present population and will not likely until the turn of the century. Therefore, the World Health Organization must, with the backing of the developed and developing nations, pursue a strong family planning program. Another method to curb population growth is to speed up economic development, creating a society in which the female plays a more important and active part so that childbearing becomes less of a natural requirement for many young women in developing countries. Other disincentives can also be created by formulating a child tax to be imposed after a family has two children. Also, raising the level of education of the females usually results in fewer children raised per female.

In research and dissemination of new technology and techniques, the developing countries must very carefully design and develop techniques that fit into the economic setting of the region for which it is intended. Developing countries must use technologies of a less capital intensive nature than what the industrial nations use today. Improved, although still labor-intensive, equipment and techniques must be available in these nations.

For the efficient allocation of resources it is necessary to point out that over time an optimal worldwide allocation of resources must be pursued. An efficient allocation of resources will contribute to a greater economic output at no greater cost to society as a whole. Also, removing international barriers to trade and dispensing with protectionism, the world can move closer to a Pareto optimum.

CHAPTER VII. SUMMARY, CONCLUSIONS AND LIMITATIONS

The objective of this study is to examine the role U.S. agriculture can play in providing world population with an adequate level of food. To accomplish this objective a model is built that encompasses 118 countires which represent more than 98 percent of the current world population. The population for each individual country is divided into 17 age and sex classes. Projections are made for each class to 1980 incorporating recent population estimates and growth rates. Depending upon location, the countries are then divided into three climatological and geographical zones: the temperate zone, the subtropical zone, and the tropical zone.

Food consumption in each of these zones is estimated based on two different assumptions. The first assumes a situation where the level of consumption is determined by economic variables, resulting in an effective demand. The second assumption describes a situation where each individual must consume at least at the level of a daily recommended allowance based on age, sex, and geographical location.

Production of over 30 food commodities is projected to 1980 based upon historical trend (for all countries but the United States). Given estimates for both consumption and production, the food deficit can be calculated. The assumption is made that any actual deficit (expressed in calories) must be supplied by the United States up to the limit of its production capacity. The deficit will be made up by wheat, feed grains and soybeans.

To provide quantitative estimates of U.S. production an interregional linear programming model is adapted incorporating the wheat, feed grains, soybeans, cotton, and corn and silage sectors. The model consists of 150 producing regions, 31 demand regions, and includes an interregional comparative advantage production sector, a transportation submodel, and requires the fulfillment of consumer demands in the 31 demand regions.

The model analyzes changes required in land uses in individual re-regions, crop production, interregional production shifts, and commodity prices.

To evaluate the impact of future export levels on American agriculture a base model and six alternative futures were determined. In each of these alternatives one or two parameters are changed with respect to the base model. The base model represents a continuation of present trend in yields, per capita food consumption, and exports. The base model (Alternative A) is solved for 1980.

The alternative futures (Alternatives B-F) can be combined into two groups. The first group analyzes changes in projected demand and export levels on the nation's agriculture. The second group deals with changes in world weather conditions and consumption patterns on land use, production patterns, prices, and the world food deficit.

The first alternative (Alternative A) assumes all-out production of U.S. agriculture in order to maximize the quantity of grains exported. Alternative B requires the world to consume at recommended daily allowances in order to meet world food requirements. Alternative C projects a level of exports that is a combination of effective demand of the developed countries and consumption requirements of the developing countries. Alternative D simulates a crop shortfall and its effect on export. The fifth alternative (Alternative E) assumes the developed nations reduce meat consumption, while Alternative F assumes everyone will reduce meat consumption but is allowed to substitute soy protein.

The results of the base model and the alternatives indicate that agriculture has a large capacity to produce higher levels of output but in only two instances could the food requirements of the world be met. In the remaining four alternatives starvation and malnutrition would continue.

The results of the base model, Alternative A, stand by themselves. The outcomes are a reflection of the construction of the model's coefficients. Alternative A will, therefore, serve as a benchmark with which the other alternatives can be compared. The results of Alternative A show that wheat and feed grains have a tremendous production potential. The projected production increases in 1980 require an increase in cropland of about 9 million acres. The additional land drawn into production is located in the Great Plains and the Corn Belt. Yield increases, compared to the actual 1973-75 figures, have taken place mainly because of projected increases in technology. Despite the increase in production, a world food deficit of almost 58 million metric tons results. It is estimated that 375 million people will starve because of the projected food gap.

The results of Alternative B indicate that consumption at the daily recommended allowance level for everyone results in adequate food for the world. United States agriculture does not require all of its available cropland resulting in relatively lower supply prices. The marginal areas not required now for production are located in the Northern Plains, South East, and Corn Belt regions.

Alternative C makes extremely large demands on American agriculture. World consumption is at the highest level under this alternative resulting in high supply prices, drawing into production the marginal areas--mainly the Northern Plains. In spite of large exports, over 2 billion bushels of wheat and 730 million bushels of soybeans, the food gap widens to 113 million metric tons of grain.

Adverse weather conditions throughout the world prevent mankind from obtaining sufficient food under Alternative D. A shortage of 23 million tons of grain results in an estimated 147 million people starving. Land is once again the limiting factor of production.

Alternative E assumes that the industrialized countries will reduce meat consumption. Although land is now made available for grain production for human consumption rather than beef consumption, production is not sufficient to meet food requirements. The U.S. production and consumption effort results in extremely large exports of wheat (2.4 billion bushels), feed grains (52 million tons), and soybeans (878 million bushels). With all land drawn into production there still exists a 32-million-ton grain deficit. Supply prices are lower relative to the base alternative.

Finally, the results of Alternative F indicate adequate food supplies for the world if everyone substitutes soy protein for an equal reduction in animal protein. So great is this grain-saving measure that an estimated 24 million acres are not required for grain production in the United States, resulting in low supply prices relative to the base alternative. In addition, production was reduced by 15 percent in the main producing and export countries, simulating adverse weather conditions.

With all the results evaluated, what are the implications? First, the results show that if the world continues to produce and consume according to trend levels, food will not be produced in sufficient quantity to prevent starvation. Thus, there is no tendency for the food situation to correct itself. Second, despite a large export effort on the part of U.S. agriculture and modest reductions in meat consumption in the industrialized nations, a food deficit remains. Third, only in the case where large consumption sacrifices are made worldwide (alternatives B and F) can enough food be produced. However, these alternatives tend to have detrimental effects on the rural communities associated with the livestock industries.

Conclusions

This study has taken a critical look at the world food situation and its possibilities and has pointed out areas where stimuli need to be applied. Lest confusion is generated, economic theory recognizes two directions, namely a) positive economics and b) normative economics. The business of an economist is a positive one. That is, given a social objective, the economist can analyze the problem and suggest ways and means to attain the desired ends. Social objectives have been set in this study (normative). Then a model is developed and recommendations are made on how to reach the set objectives by the most efficient means (positive).

Main conclusions that can be drawn from this study include:

1. World food productive capacity is large enough to support the current population.
2. World food production is too small to provide a buffer in times of less-than-trend production, if no adequate reserves are held.
3. Population growth rates in the developing countries are too high to allow increases in per capita consumption in these areas.
4. Reducing post-harvest food losses by 50 percent would almost erase existing food deficits. Johnson concluded that he does not know how much food waste does actually take place. But he says: ". . . I wish that food waste in the developing countries did average 25 percent; a concerted effort to reduce such waste to 15 percent could probably be mounted at less cost than a program to increase food production by 10 percent" (Johnson, 1975). Research and development must be channeled into the not so "glamorous" area of post-harvest food losses and food processing.

   be mounted at less cost than a program to increase food production by 10 percent" (Johnson, 1975). Research and development must be channeled into the not so "glamorous" area of post-harvest food losses and food processing.
5. A major cause of famine and starvation is because of a malfunction of the distribution system. Developing countries must be stimulated and guided into building and improving an infra-

structure that is capable of handling the demands that society wishes to make of it.

6. Trade and other barriers must be removed to let resources flow freely across borders so that we can more nearly equate marginal products to price and to marginal rates of transformation. The immediate result will be increased output at no greater cost.
7. An increased effort must be made in funding research programs of crop and livestock production adopted to local conditions along the lines of the international research institutes.
8. An intensive extension education program must be mounted for the farming and rural population of the developing countries. The basic skills of understanding the complete package of requirements in the Green Revolution, irrigation management, and other techniques associated with improved farming must be taught.
9. The crux of the world food problem seems to be the lack of a basic commitment by governments to implement a set of policies described above. Procrastination on these issues only serves to widen the gap between being "well fed" and starvation.

Limitations of This Study

A number of limitations of data and procedures should be acknowledged. Because an important part of this study draws upon data for all food crops for almost all countries in the world, the accuracy of the data leaves much to be desired. Also, the data base is relatively old. Although part of the data incorporates the results of the Green Revolution, it does not include the 1972-75 period of high energy prices, high fertilizer prices, and high grain prices. Much of the data for developing countries (consumption, production, stocks) is of low quality. Also the data for the communist countries are unknown or are of low quality.

Obtaining estimates on world consumption, or recommended diets, is a complicated procedure and requires a degree of detail that is almost impossible to obtain. This study does not claim to have put together the acceptable or optimal diet. All it has done is compose a diet, in more or less historic proportions, that contains adequate calories, and if well-balanced, also adequate proteins. Until each individual country makes up a diet that contains recommended allowances for all ages and sexes, the researcher has to make do with improvised food schemes. Current growth rates for each individual country and the demographic distribution are held constant for the period under investigation.

The estimates on food exports in some of the alternatives may be underestimated. As was experienced in 1973 because of the high export demand, high grain prices forced farmers to liquidate livestock, resulting in a grain savings of over 20 million metric tons. Also, in the alternative where consumers are forced to reduce meat consumption, the land freed from grazing is not drawn into production which underestimates production somewhat.

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As one progresses through life from one stage to the next, one is excited but at the same time a little sad for having to step out of a period of which one seems only to remember the good times. As the French say: "Partir est un peu mourir." Leaving is a little bit dying.

Starting an academic education relatively late in life, obtaining the goal which I had set for myself while in Zambia, has presented me with an enormous challenge for little over six years. Now, new horizons are unfolding and are waiting to be explored. New challenges will present themselves. I am ready for them.

The production of a dissertation is but one requirement to finish up, but it is almost the only opportunity for a graduate student to show himself and the rest of the profession what he is capable of. I have tried to do just that. Great ideas brew in my imagination, but when I set out to get it done it soon became apparent that certain trade-offs would have to be made between what I <u>aspired</u> to do and what I <u>could</u> do.

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APPENDIX A

Table A. Per capita base consumption, base period 1964-66 average and estimated per capita consumption in 1980 for a selected country

Mexico Commodity Code	Item	QUANT KG/Year	Calories Per Day	Proteins Per Day	Fats Per Day	QUANT KG/Year
			1965			1980
1	Cereals	138.3	1,366	35.9	13.2	128.1
2	Wheat	20.7	206	6.2	.6	24.6
3	Rice	4.1	40	.7	.1	4.6
4	Coarse Grains	113.3	1,120	29.0	12.5	98.6
5	Starchy Roots	11.7	39	.4	-	13.0
6	Sugar Products	40.5	421	.2	-	43.4
7	Pulses, Nuts, Seeds	24.9	225	14.0	3.0	23.1
8	Vegetables	13.4	7	.4	-	16.3
9	Fruits	75.9	98	1.2	.7	93.7
10	Bananas	19.3	35	.5	.2	22.6
11	Other Fruits	36.3	46	.4	.5	47.3
12	Meat	20.1	140	6.9	12.1	25.0
13	Beef and Veal	7.2	44	2.9	3.5	9.1
14	Mutton and Lamb	1.2	6	.5	.4	1.3
15	Pig Meat	7.1	74	1.9	7.3	8.7
16	Eggs	3.8	15	1.1	1.1	5.5
17	Fish	3.3	6	.8	.3	4.3
18	Whole Milk	36.1	65	3.4	3.4	50.7
19	Skim Milk	10.7	17	1.0	-	13.5
20	Cheese	1.5	15	1.0	1.2	1.5
21	Fats and Oils	8.0	201	-	22.6	10.3
22	Spices	.5	21	.2	.1	.6
23	Cocoa	.3	4	-	.4	.3
	Total Food		2,623	66.5	58.1	
	(Animal)		(285)	(14.2)	(21.1)	
	Calories	2,623				2,698
	Animal Calories	285				367
	Protein	66.5				67.4
	Animal Protein	14.2				18.3
	Fats	58.1				68.6
	Animal Fats	21.1				26.9

APPENDIX B. MATHEMATICAL STRUCTURE OF THE MODEL

The mathematical model used for this study is a linear programming model, which minimizes the cost of producing the five endogenous commodities in the 150 producing regions and the transportation of these commodities (except for silage) among the 31 demand regions.

The model consists of 307 equations and 2,214 real variables. Land in the 150 rural areas and demands specified for the 31 consuming regions (plus national cotton lint demand) serve as constraints for the equations. The real variables include crop production and transportation activities.

In mathematical notation we may write the model as follows:

Find a set of x's such that

$$f(x) = CX \tag{B.1}$$

is minimized subject to

$$Ax \leqq b \tag{B.2}$$

$$x \geqq 0 \tag{B.3}$$

where:

x = column vector of production and transportation activities;

C = row vector of unit costs for the activities;

A = a matrix of input-output coefficients; and

b = column vector of resource restraints and demand requirements.

The mathematical structure for all six alternatives stays the same. The factors, which do vary between the alternatives, are the assumptions concerning the value of the model parameters (export levels for the endogenous commodities and domestic consumption levels).

Equation B.4 is the objective function to be minimized in the model:

$$f(c) = \sum_{i=1}^{150} \sum_{j=1}^{5} C_{ij}^{s} x_{ij} + \sum_{f=1}^{31} \sum_{l=1}^{31} \sum_{j=1}^{4} T_{flr} z_{mfr} \qquad (B.4)$$

where:

C_{ij}^{s} = the cost per acre of producing the jth crop activity in the ith rural area for farm-size structure s (j = 1,2,3,4,5 for wheat, feed grains, soybeans, cotton, and silage, respectively);

x_{ij} = the number of acres of the jth crop activity in ptoduction in the ith rural area;

T_{mfr} = the cost of transporting one ton of the rth commodity to (from) the mth demand region from (to) the fth demand region ($m \neq f$; r = 1,2,3,4 for spring and winter wheat, feed grains, and oilmeals, respectively); and

z_{mfr} = the tons of the rth commodity transported from (to) the mth demand region to (from) the fth demand region.

Production of the crop commodities is restrained by the total cropland available in each rural area, equation B.5:

$$L_i = \sum_{j=1}^{5} x_{ij} \qquad (i = 1,2,\ldots,150) \qquad (B.5)$$

while the production of soybeans is additionally restrained by an agronomic restraint, equation B.6

$$x_{i3} \leq A_i L_i \qquad (i = 1,2,\ldots,150) \qquad \text{(B.6)}$$

where:

L_i = the total acreage of land available for the five crop commodities in the ith rural area;

A_i = the proportion of the total amount of land available to soybean production in the ith rural area (A_i = .5 for all rural areas except those in Arkansas, Louisiana, and Mississippi where A_i = .7); and

x_{ij} = defined as before.

In addition to the upper limits on production in Equations B.5 and B.6, minimum production restraints are imposed in each rural area as in equation B.7:

$$x_{ij} \geq B_{ij} \qquad (i = 1,2,\ldots,150;\ j = 1,2,3,4,5) \qquad \text{(B.7)}$$

where:

B_{ij} = 50 percent of the acreage of the jth crop harvested in ith rural area in 1969; and

x_{ij} = defined as before.

Equation B.4 is minimized subject to the following additional linear demand restraints:

$$D_{mi} \leq \sum_{i=1}^{n} Y_{il} x_{il} \pm \sum_{f=1}^{31} z_{mfl} \qquad \text{(B.8)}$$

$$(m = 1,2,\ldots,31;\ f \neq m)$$

$$D_{m2} \leq \sum_{i=1}^{n} Y_{i2}x_{i1} \pm \sum_{f=1}^{31} z_{mf2} \tag{B.9}$$

$(m = 1,2,\ldots,31;\ f \neq m)$

$$D_{m3} = \sum_{i=1}^{n} Y_{i3}x_{i2} \pm \sum_{f=1}^{31} z_{mf3} \tag{B.10}$$

$(m = 1,2,\ldots,31;\ f \neq m)$

$$D_{m4} = \sum_{i=1}^{n} Y_{i4}x_{i3} + \sum_{i=1}^{n} Y_{i4}x_{i4} \pm \sum_{f=1}^{31} z_{mf4} \tag{B.11}$$

$(m = 1,2,\ldots,31;\ f \neq m)$

$$D_{5} = \sum_{i=1}^{150} Y_{i5}x_{i4} \tag{B.12}$$

$$D_{m6} = \sum_{i=1}^{n} Y_{i6}x_{i5} \tag{B.13}$$

where:

n = the number of rural areas in the mth consuming region;

D_{mr} = the tons of the rth commodity demanded in the mth consuming region (r = 1,2,3,4,6 for spring wheat, winter wheat, feed grains, oilmeals, and silage, respectively);

D_5 = the national demand for cotton lint (in 480-pound bales);

Y_{ir} = the yield in tons (except for cotton lint which is in 480-pound bales) of the rth commodity in the ith rural area (r = 1,2,3,4,5,6 for spring wheat, winter wheat, feed grains, oilmeals, cotton line, and silage); and

x_{ij} and z_{mfr} = defined as before.

Finally, we have the usual nonnegativity assumptions of linear programming:

$$x_{ij} \geqq 0; \; z_{flr} \geqq 0. \tag{B.14}$$

APPENDIX C. CONSUMPTION OF LIVESTOCK

Although the specific goal of this analysis is the estimation of exports, estimates of the domestic demands for the endogenous crop commodities are also required. Actually, these demands form a major input in the study. As suggested earlier, American consumer demand is the variable forced to change in alternatives B, E, and F. The linear programming model specifies that domestic demands (in the sense of point estimates) must be satisfied before any grain is available for exports. Because livestock generates a large component of domestic demand for feed grains and soybeans and because per capita meat consumption is a variable of interest in this study, the demand estimates for meat are explained in this appendix.

Beef, pork, and broiler demands are estimated from equations C.1, C.2, and C.3, respectively. These equations are developed by Waugh (1964). The demand estimates for sheep and for turkeys are given in equations C.4 and C.5, respectively, and were developed in Nicol, Heady, and Madsen (1974).

$$Q_1 = 43.7809 - 0.7697 * RP_1 + 0.2786 * RP_2 + 0.1076 * RP_3 + 0.0386 * Y \tag{C.1}$$

$$Q_2 = 90.1111 + 0.2786RP_1 - 0.9612 * RP_2 + 0.0728RP_3 + 0.0032 * Y \tag{C.2}$$

$$Q_3 = 32.0623 + 0.1076 * RP_1 + 0.0728 * RP_2 - 0.4485RP_3 + 0.0023 * Y \quad (C.3)$$

$$Q_4 = e^{5.57087} * RPI_4^{-1.9916} * RPI_1^{0.57397} * Y^{0.36813} * I^{-0.13775} \quad (C.4)$$

$$Q_5 = e^{2.40871} * RPI_5^{-0.43835} * RPI_1^{0.19729} * T^{0.21801} \quad (C.5)$$

where:

Q_i = the per capita consumption (in pounds per year) of the ith livestock product (i = 1,2,3,4,5 for beef, pork, broilers, sheep, and turkeys, respectively);

RP_i = the retail price of commodity i in 1957-59 prices;

Y = per capita disposable consumer income in 1957-59 dollars (U.S. Department of Commerce, 1968);

e = the base of the natural logarithms;

RPI_i = the retail price index for commodity i (1957-59 = 100); and

T = time in years (T = 1 in 1948).

The demand for beef, Q_1, can be partially satisfied by the slaughter of cull dairy animals. Therefore, the demand for feed grains by beef must be reduced to account for the meat production of dairy animals. Procedures given in <u>Cattle Raising in the United States</u> (U.S. Department of Agriculture, 1973a) are used to estimate dairy animal slaughter.

When equations C.3, C.4, and C.5 are compared with actual 1960-1970 data, they give unsatisfactory results especially at the latter part of the period because of shifts in consumer preferences which had occurred by that time. Therefore, the results of these equations were adjusted to reflect their estimation bias in that period. The estimates of per capita consumption for each of the five livestock classes discussed above are presented in Table C, along with recent actual data. The livestock prices are estimated quantitatively to be consistent with the feedstuff prices that result in the programming model.

Table C. Per capita consumption for selected years and prices received at farm level as used in this study

Livestock Class	Per Capita Consumption 1969-72 Average[a]	1974[a]	1980	Price at the farm level[b]
			(pounds)	(cents/pound)
Beef	115.4	109.6	131.4	48.0
Pork	66.7	61.6	61.4	37.0
Broilers	38.9	41.5	40.5	24.0
Lamb	3.2	2.7	2.7	41.0
Turkeys	9.1	8.7	9.2	22.4

[a]SOURCE: U.S. Department of Agriculture, 1973.

[b]Prices are expressed in 1972 dollars with no adjustments for inflation.

Under Alternative A, the consumption of beef in 1980 is estimated to increase by 14 percent over recent levels. Pork is projected to decrease by 8 percent. Consumption of lamb and broiler and turkey meats is estimated to change only slightly over this period.

Under alternatives B, E, and F the same projections are made for consumption in 1980. Once these estimates have been derived, however, they are further transformed. Alternative B has the American consumer reduce his consumption to DRA levels, proportionately distributed between animal and other calories. Alternative E requires the reduction of 25 percent of all meats. Thus, the levels projected for Alternative A are reduced by this percentage. Finally, Alternative F allows substitution of soy protein for the meat reduction.

The substitution of soy protein is undoubtedly feasible. Consumer resistence has resulted in human consumption of only about 3 percent of world soybean production (Heady, Faber, and Sonka, 1975).